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CDS DS210: Section B1
Final Project Report

Data

Purpose:

In general, asset prices are very difficult to predict, especially with relation to each other. However, barring any significant current events or market defining events, this project is meant to use similarity between years of data for all relevant asset classes, in order to provide recommendations between them.

By analyzing around four years of historical data across many different assets, I want to make predictions for the next four years. For example, throughout this project, we will see if the GBP is doing well 72 days after we start another project like this, then those that are heavily correlated with it may do well on the corresponding day.

In case the data does not load, it can be found:
https://github.com/julian-west/asset_price_correlations/tree/master/data

Goals:

1. Find related assets, specifically those increasing/decreasing together.
2. Take into account each users' risk tolerance and based on their current holdings, create a diversified or homogeneous portfolio.

Code Walkthrough

Read-In (fn read)

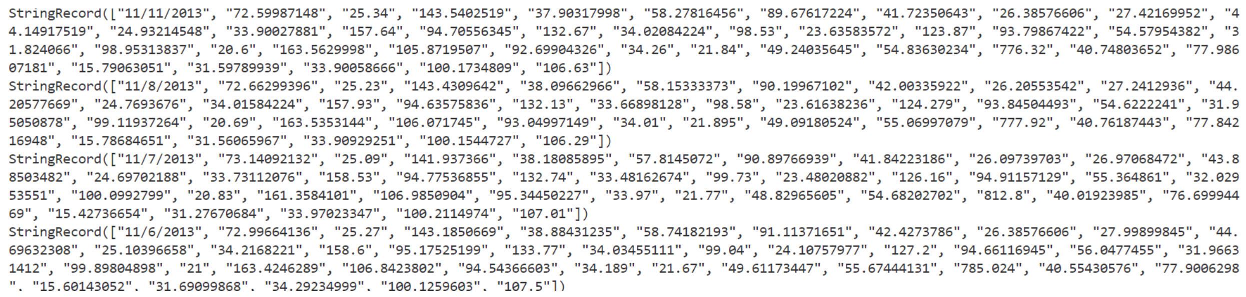
We read in our data using the read function in the main file. It takes in the local path of our csv file and turns it into a digestible format. For this, I involved the csv::reader, read in preliminary data like the headers (column names) and the baseline data (which is represented by the last row in this data, as it is in reverse chronological order). Due to the large number of vertices (originally over 30,000), I also only took a subset of this data at 30-record intervals. This subset is still greater than the required 1000-nodes for this project.

After collecting this preliminary data, I find the log-return value for each asset on each day (returns from the baseline value). This is because assets are usually normalized and compared according to their log-return value. This value is also useful in creating edges according to correlation between each node.

After finding this value, I push the label (date & asset) and the corresponding log-return to a vector called "Nodes". I also create a Hashmap (Assetprices) with each asset type (determined by the column name) and the corresponding log returns throughout our time frame.

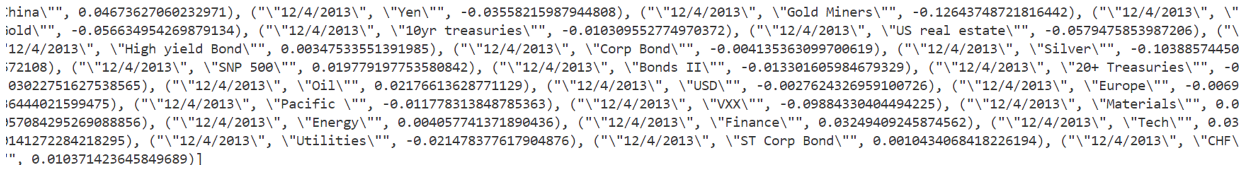
This function returns Nodes and Assetprices.

In assetprices, each record represents a date and the corresponding asset prices on that date. The following is a subset of how this read-in looks.



```
StringRecord(["11/11/2013", "72.59987148", "25.34", "143.5402519", "37.90317998", "58.27816456", "89.67617224", "41.72350643", "26.38576606", "27.42169952", "4
4.14917519", "24.93214548", "33.90027881", "157.64", "94.70556345", "132.67", "34.02084224", "98.53", "23.63583572", "123.87", "93.79867422", "54.57954382", "3
1.824066", "98.95313837", "20.6", "163.5629998", "105.8719507", "92.69904326", "34.26", "21.84", "49.24035645", "54.83630234", "776.32", "40.74803652", "77.986
07181", "15.79063051", "31.59789939", "33.90058666", "100.1734809", "106.63"])
StringRecord(["11/8/2013", "72.66299396", "25.23", "143.4309642", "38.09662966", "58.15333373", "90.19967102", "42.00335922", "26.20553542", "27.2412936", "44.
20577669", "24.7693676", "34.01584224", "157.93", "94.63575836", "132.13", "33.66898128", "98.58", "23.61638236", "124.279", "93.84504493", "54.6222241", "31.9
5050878", "99.11937264", "20.69", "163.5353144", "106.071745", "93.04997149", "34.01", "21.895", "49.09180524", "55.06997079", "777.92", "40.76187443", "77.842
16948", "15.78684651", "31.56065967", "33.90929251", "100.1544727", "106.29"])
StringRecord(["11/7/2013", "73.14092132", "25.09", "141.937366", "38.18085895", "57.8145072", "90.89766939", "41.84223186", "26.09739703", "26.97068472", "43.8
8503482", "24.69702188", "33.73112076", "158.53", "94.77536855", "132.74", "33.48162674", "99.73", "23.48020882", "126.16", "94.91157129", "55.364861", "32.029
53551", "100.0992799", "20.83", "161.3584101", "106.9850904", "95.34450227", "33.97", "21.77", "48.82965605", "54.68202702", "812.8", "40.01923985", "76.699944
69", "15.42736654", "31.27670684", "33.97023347", "100.2114974", "107.01"])
StringRecord(["11/6/2013", "72.99664136", "25.27", "143.1850669", "38.88431235", "58.74182193", "91.11371651", "42.4273786", "26.38576606", "27.99899845", "44.
69632308", "25.10396658", "34.2168221", "158.6", "95.17525199", "133.77", "34.03455111", "99.04", "24.10757977", "127.2", "94.66116945", "56.0477455", "31.9663
1412", "99.89804898", "21", "163.4246289", "106.8423802", "94.54366603", "34.189", "21.67", "49.61173447", "55.67444131", "785.024", "40.55430576", "77.9006298
", "15.60143052", "31.69099868", "34.29234999", "100.1259603", "107.5"])
```

The following is a small output of Nodes, which represents all of our data in a digestible format for our program to read.

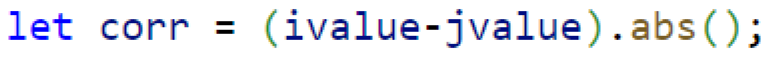


```
hina\"", 0.04673627060232971), ("\"12/4/2013\", \"Yen\"", -0.03558215987944808), ("\"12/4/2013\", \"Gold Miners\"", -0.12643748721816442), ("\"12/4/2013\", \"
old\"", -0.056634954269879134), ("\"12/4/2013\", \"10yr treasuries\"", -0.010309552774970372), ("\"12/4/2013\", \"US real estate\"", -0.0579475853987206), ("\
12/4/2013\", \"High yield Bond\"", 0.00347533551391985), ("\"12/4/2013\", \"Corp Bond\"", -0.004135363099700619), ("\"12/4/2013\", \"Silver\"", -0.10388574450
72108), ("\"12/4/2013\", \"SNP 500\"", 0.019779197753580842), ("\"12/4/2013\", \"Bonds II\"", -0.013301605984679329), ("\"12/4/2013\", \"20+ Treasuries\"", -0
03022751627538565), ("\"12/4/2013\", \"Oil\"", 0.02176613628771129), ("\"12/4/2013\", \"USD\"", -0.0027624326959100726), ("\"12/4/2013\", \"Europe\"", -0.0069
6444021599475), ("\"12/4/2013\", \"Pacific \"", -0.011778313848785363), ("\"12/4/2013\", \"VXX\"", -0.09884330404494225), ("\"12/4/2013\", \"Materials\"", 0.0
5708429526908856), ("\"12/4/2013\", \"Energy\"", 0.004057741371890436), ("\"12/4/2013\", \"Finance\"", 0.03249409245874562), ("\"12/4/2013\", \"Tech\"", 0.03
141272284218295), ("\"12/4/2013\", \"Utilities\"", -0.021478377617904876), ("\"12/4/2013\", \"ST Corp Bond\"", 0.0010434068418226194), ("\"12/4/2013\", \"CHF\
", 0.010371423645849689)]
```

Adjacency (Adjacent Mod)

Since we found the nodes, all that's left before we are able to create the graph is finding the edges between these nodes. We do this through the createadj function in the Adjacent mod. It takes in the list of Nodes from the read function, the size of Nodes, and a threshold. This function creates a Hashmap, "Edges", and an (differently styled) Adjacency Matrix, "Matrix". Although the traditional adjacency matrix would have 2 columns and an indicator of whether these nodes share an edge, the matrix we use here has n columns and n rows and True/False values at [i][j] depending on if there is an edge there. The main part of this function is a nested for-loop. For each Node, it accesses all other nodes and sees if the correlation between these two assets' log returns is less than or equal to the threshold. (Concession: I originally planned to find cosine similarity between each asset but realized this is not applicable to the way I read in the data. Although distance between returns may not be the best indicator of correlation, I was able to find resources that supported that this may be a good comparison point nonetheless: Here, and Here)

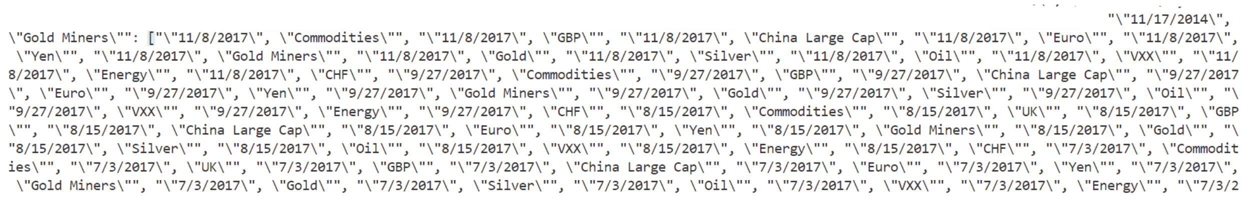
Since we are measuring correlation by distance, as shown below, the lower the better. Therefore, the function then creates an edge between these two values by adding the jlabel as a value to the ilabel key in Edges. It also marks [i][j] as True, indicating an edge, in our Matrix.



```
let corr = (ivalue-jvalue).abs();
```

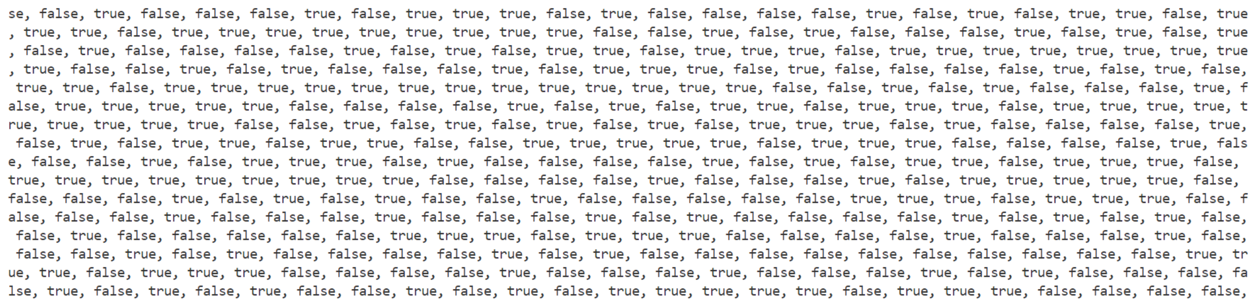
This function returns the Adjacency List (HashMap) and the Matrix.

This is a subset of the adjlist that shows the adjacency list for Gold Miners 11/17/2014):



```
                                                                                                              "\"11/17/2014\",
\"Gold Miners\"": ["\"11/8/2017\", \"Commodities\"", "\"11/8/2017\", \"GBP\"", "\"11/8/2017\", \"China Large Cap\"", "\"11/8/2017\", \"Euro\"", "\"11/8/2017\",
 \"Yen\"", "\"11/8/2017\", \"Gold Miners\"", "\"11/8/2017\", \"Gold\"", "\"11/8/2017\", \"Silver\"", "\"11/8/2017\", \"Oil\"", "\"11/8/2017\", \"VXX\"", "\"11/
8/2017\", \"Energy\"", "\"11/8/2017\", \"CHF\"", "\"9/27/2017\", \"Commodities\"", "\"9/27/2017\", \"GBP\"", "\"9/27/2017\", \"China Large Cap\"", "\"9/27/2017
\", \"Euro\"", "\"9/27/2017\", \"Yen\"", "\"9/27/2017\", \"Gold Miners\"", "\"9/27/2017\", \"Gold\"", "\"9/27/2017\", \"Silver\"", "\"9/27/2017\", \"Oil\"", "\
"9/27/2017\", \"VXX\"", "\"9/27/2017\", \"Energy\"", "\"9/27/2017\", \"CHF\"", "\"8/15/2017\", \"Commodities\"", "\"8/15/2017\", \"UK\"", "\"8/15/2017\", \"GBP
\"", "\"8/15/2017\", \"China Large Cap\"", "\"8/15/2017\", \"Euro\"", "\"8/15/2017\", \"Yen\"", "\"8/15/2017\", \"Gold Miners\"", "\"8/15/2017\", \"Gold\"", "\
"8/15/2017\", \"Silver\"", "\"8/15/2017\", \"Oil\"", "\"8/15/2017\", \"VXX\"", "\"8/15/2017\", \"Energy\"", "\"8/15/2017\", \"CHF\"", "\"7/3/2017\", \"Commodit
ies\"", "\"7/3/2017\", \"UK\"", "\"7/3/2017\", \"GBP\"", "\"7/3/2017\", \"China Large Cap\"", "\"7/3/2017\", \"Euro\"", "\"7/3/2017\", \"Yen\"", "\"7/3/2017\",
 \"Gold Miners\"", "\"7/3/2017\", \"Gold\"", "\"7/3/2017\", \"Silver\"", "\"7/3/2017\", \"Oil\"", "\"7/3/2017\", \"VXX\"", "\"7/3/2017\", \"Energy\"", "\"7/3/2
```

We also get the following adjacency matrix (same information but iterable easily with [i][j]]):



```
se, false, true, false, false, false, true, false, true, true, true, false, true, false, false, false, false, true, false, true, false, true, true, false, true
, true, true, false, true, true, true, true, true, true, true, true, true, false, false, true, false, true, false, false, false, true, false, true, false, true
, false, true, false, false, false, false, true, false, true, false, true, true, false, true, true, true, false, true, true, true, true, true, true, true, true
, true, false, false, true, false, true, false, false, false, true, false, true, true, true, false, true, false, false, false, false, true, false, true, false,
 true, true, false, true, true, true, true, true, true, true, true, true, true, true, true, true, false, false, true, false, true, false, false, false, true, f
alse, true, true, true, true, true, false, false, false, false, true, false, true, false, true, true, false, true, true, true, false, true, true, true, true, t
rue, true, true, true, true, false, false, true, false, true, false, true, false, true, false, true, true, true, false, true, false, false, false, false, true,
 false, true, false, true, true, false, true, true, false, false, true, true, true, true, true, false, true, true, true, false, false, false, false, true, fals
e, false, false, true, false, true, true, true, false, true, false, false, false, false, true, false, true, false, true, true, false, true, true, true, false,
true, true, true, true, true, true, true, true, true, false, false, false, false, true, false, false, false, true, false, true, true, true, true, true, false,
false, false, false, true, false, true, false, true, false, false, true, false, false, false, false, false, true, true, true, false, true, true, true, false, f
alse, false, false, true, false, false, false, true, false, false, false, true, false, true, false, false, false, false, true, false, true, false, true, false,
 false, true, false, false, false, false, false, true, true, true, false, true, true, true, false, false, false, false, true, false, false, false, true, false,
 false, false, true, false, true, false, false, false, false, true, false, true, false, false, false, false, false, false, false, false, false, false, true, tr
ue, true, false, true, true, true, false, false, false, false, true, false, false, false, true, false, false, false, true, false, true, false, false, false, fa
lse, true, false, true, false, true, false, false, true, false, true, false, true, true, true, true, true, false, true, true, true, false, false, false, false,
```

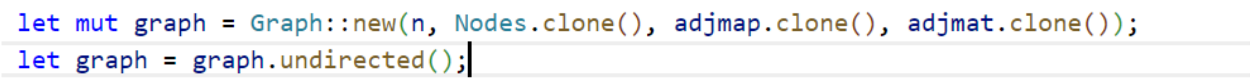
Additionally, since the threshold is something that can be changed when calling the function, this adjacency list serves two purposes:

1. Calculating the assets with most similar performance (as traditionally used, when threshold is set to > 0.5)
2. Calculating the least correlated/negatively correlated assets. For example, if threshold is set to -0.5, the adjacency list will provide values that are negatively correlated

Creating Graph (Mod Create)

To create the graph itself, we move to our create module. Here, I start with a Graph struct; this consists of the size of the graph (n/number of nodes), a list of vertices, and both the Adjacency list and Adjacency Matrix.

In our main function, we create the graph like this:



```rust
let mut graph = Graph::new(n, Nodes.clone(), adjmap.clone(), adjmat.clone());
let graph = graph.undirected();
```

We get Nodes as an output of our read function, n is the size of Nodes, and adjmap and adjmat both come from our adjacency function.

I create a graph using the new and undirected functions. New takes all of our inputs and feeds them into the struct. We don't have to do much for making sure our graph is undirected since the createadj function iterates over every node, finding bipartite edges. However, this undirected function makes our self.vertices easier to read by sorting them per the label.

Recommendations:

Daily Expect:

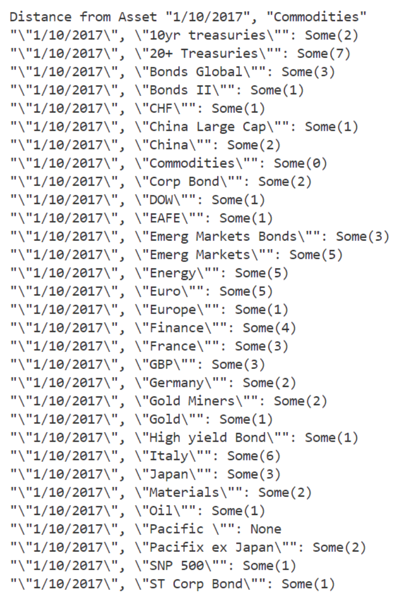
Our graph is now created. We can apply it to our preliminary objectives for this project from earlier. Although this is a more elementary output, our dailyexpect method takes in the graph and a minimum return value, and throws out two vectors, one with assets with positive returns, and another with negative. This function helps to address our first goal of finding similarities for assets across our timeframe. For the purposes of this project, I set the threshold = to 0.0. However, for someone who wants higher returns, this threshold can also be higher. This method is also helpful in seeing if the data was read in correctly, and if log returns were computed correctly. We will use it as a test later.

Portfolio & Risk:

Next, we come to our joint methods, portfolio and risk. Risk is a BFS algorithm that produces a vector of distances from each node to the rest, as measured by neighbors between the nodes in question. It starts with an empty queue, pushes our starting vertex to it, and as long as there is a queue, it explores the neighbors for the first value in this queue. It accesses this vertex in the adjacency matrix we made earlier (hence why it wasn't a traditional adjacency matrix), and if it is true that our current vertex shares an edge with this target, then the corresponding distance for this point is 1+=distance to the value we accessed through our while loop. This value is then added to the queue and the process is repeated until there is nothing in the queue. This happens when we have either reached all nodes, no matter how far, or if no matter how many nodes we iterate over, there are some that are unreachable.

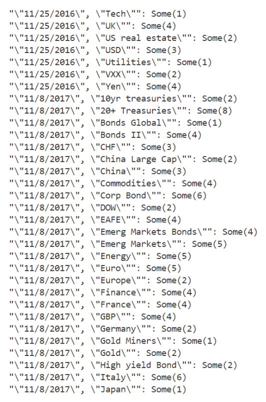
The portfolio method calls the risk method for all vertices. In principle, this is a nested for loop (but the second loop may not include all n in vertices if they don't have neighbors.

This is a snippet of the output. As we can see, it described the distance between the node representing Commodities on 1/10/2017 and the other nodes in our data. Sense check, this is a valid output because the distance back to commodities on 1/10/2017 is 0 while the distance to pacific on the same day is None. Pacific on 1/10/2017 is likely an outlier in a different component (which we will explore later).



```
Distance from Asset "1/10/2017", "Commodities"
"\"1/10/2017\", \"10yr treasuries\"": Some(2)
"\"1/10/2017\", \"20+ Treasuries\"": Some(7)
"\"1/10/2017\", \"Bonds Global\"": Some(3)
"\"1/10/2017\", \"Bonds II\"": Some(1)
"\"1/10/2017\", \"CHF\"": Some(1)
"\"1/10/2017\", \"China Large Cap\"": Some(1)
"\"1/10/2017\", \"China\"": Some(2)
"\"1/10/2017\", \"Commodities\"": Some(0)
"\"1/10/2017\", \"Corp Bond\"": Some(2)
"\"1/10/2017\", \"DOW\"": Some(1)
"\"1/10/2017\", \"EAFE\"": Some(1)
"\"1/10/2017\", \"Emerg Markets Bonds\"": Some(3)
"\"1/10/2017\", \"Emerg Markets\"": Some(5)
"\"1/10/2017\", \"Energy\"": Some(5)
"\"1/10/2017\", \"Euro\"": Some(5)
"\"1/10/2017\", \"Europe\"": Some(1)
"\"1/10/2017\", \"Finance\"": Some(4)
"\"1/10/2017\", \"France\"": Some(3)
"\"1/10/2017\", \"GBP\"": Some(3)
"\"1/10/2017\", \"Germany\"": Some(2)
"\"1/10/2017\", \"Gold Miners\"": Some(2)
"\"1/10/2017\", \"Gold\"": Some(1)
"\"1/10/2017\", \"High yield Bond\"": Some(1)
"\"1/10/2017\", \"Italy\"": Some(6)
"\"1/10/2017\", \"Japan\"": Some(3)
"\"1/10/2017\", \"Materials\"": Some(2)
"\"1/10/2017\", \"Oil\"": Some(1)
"\"1/10/2017\", \"Pacific \"": None
"\"1/10/2017\", \"Pacifix ex Japan\"": Some(2)
"\"1/10/2017\", \"SNP 500\"": Some(1)
"\"1/10/2017\", \"ST Corp Bond\"": Some(1)
```

This is another snippet of the same output for further reference:



```
"\"11/25/2016\", \"Tech\"": Some(1)
"\"11/25/2016\", \"UK\"": Some(4)
"\"11/25/2016\", \"US real estate\"": Some(2)
"\"11/25/2016\", \"USD\"": Some(3)
"\"11/25/2016\", \"Utilities\"": Some(1)
"\"11/25/2016\", \"VXX\"": Some(2)
"\"11/25/2016\", \"Yen\"": Some(4)
"\"11/8/2017\", \"10yr treasuries\"": Some(2)
"\"11/8/2017\", \"20+ Treasuries\"": Some(8)
"\"11/8/2017\", \"Bonds Global\"": Some(1)
"\"11/8/2017\", \"Bonds II\"": Some(4)
"\"11/8/2017\", \"CHF\"": Some(3)
"\"11/8/2017\", \"China Large Cap\"": Some(2)
"\"11/8/2017\", \"China\"": Some(3)
"\"11/8/2017\", \"Commodities\"": Some(4)
"\"11/8/2017\", \"Corp Bond\"": Some(6)
"\"11/8/2017\", \"DOW\"": Some(2)
"\"11/8/2017\", \"EAFE\"": Some(4)
"\"11/8/2017\", \"Emerg Markets Bonds\"": Some(4)
"\"11/8/2017\", \"Emerg Markets\"": Some(5)
"\"11/8/2017\", \"Energy\"": Some(5)
"\"11/8/2017\", \"Euro\"": Some(5)
"\"11/8/2017\", \"Europe\"": Some(2)
"\"11/8/2017\", \"Finance\"": Some(4)
"\"11/8/2017\", \"France\"": Some(4)
"\"11/8/2017\", \"GBP\"": Some(4)
"\"11/8/2017\", \"Germany\"": Some(2)
"\"11/8/2017\", \"Gold Miners\"": Some(1)
"\"11/8/2017\", \"Gold\"": Some(2)
"\"11/8/2017\", \"High yield Bond\"": Some(2)
"\"11/8/2017\", \"Italy\"": Some(6)
"\"11/8/2017\", \"Japan\"": Some(1)
```

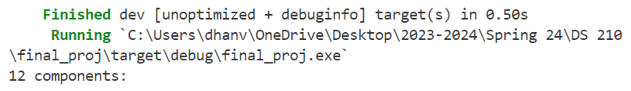
Making Groups (fn findcomp & fn groups)

Our next two methods are built very similarly in that they are independent methods but groups calls the for loop in findcomp for all nodes.

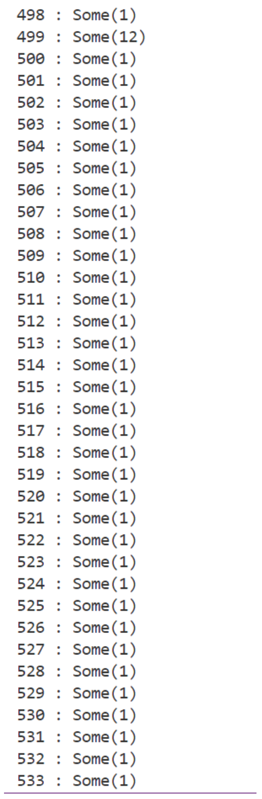
Findcomp also makes a queue and while there is a point in the queue, it will access all of the connections in the corresponding row in our adjacency matrix. If there is a connection to a different node from our point, and this new node does not have an associated component, it assigns a component that corresponds with which iteration of the for loop we are on (after which iteration we were able to access this node). It also adds this new node to the queue so that it can be explored.

Groups calls this function for all nodes that don't have a component associated with them. Each time it has to explore the neighbors of a new point, the "count variable" (the one that was assigned as the component number earlier), increments by 1, indicating that a new group is made.

There are 12 components.



```
    Finished dev [unoptimized + debuginfo] target(s) in 0.50s
     Running `C:\Users\dhanv\OneDrive\Desktop\2023-2024\Spring 24\DS 210
\final_proj\target\debug\final_proj.exe`
12 components:
```



```
498 : Some(1)
499 : Some(12)
500 : Some(1)
501 : Some(1)
502 : Some(1)
503 : Some(1)
504 : Some(1)
505 : Some(1)
506 : Some(1)
507 : Some(1)
508 : Some(1)
509 : Some(1)
510 : Some(1)
511 : Some(1)
512 : Some(1)
513 : Some(1)
514 : Some(1)
515 : Some(1)
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518 : Some(1)
519 : Some(1)
520 : Some(1)
521 : Some(1)
522 : Some(1)
523 : Some(1)
524 : Some(1)
525 : Some(1)
526 : Some(1)
527 : Some(1)
528 : Some(1)
529 : Some(1)
530 : Some(1)
531 : Some(1)
532 : Some(1)
533 : Some(1)
```
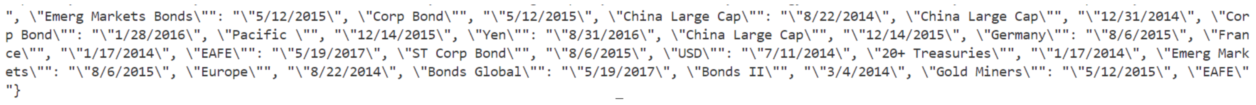

However, as we can tell by this subset of the output (on the right), most points are in one group (group 1). Meanwhile some groups, like group 12, only have about 1 point in them, meaning that they may just be outlier assets in our assessment.

Recommendations (fn recommend)

For our final graph utilization, we utilize the recommend function (housed in our main file). This function resembles a page rank. It takes in a variable number, risklevel, of iterations that represents the risk level of the user (ie: one iteration = less risky, very similar asset types while 20 iterations could result in an asset with very little similarity).

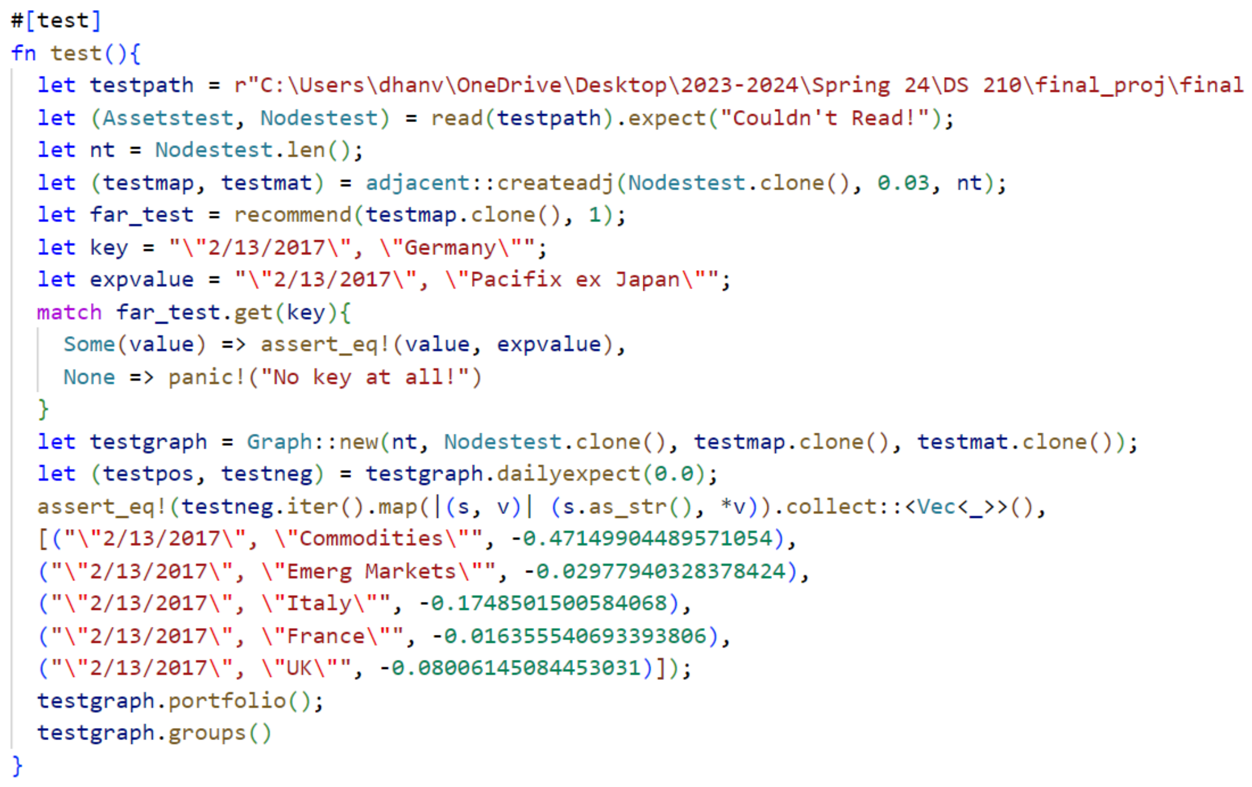
This function outputs a hashmap. For each asset, it visits *risk-level* number of other assets. It also keeps track of the assets we've visited throughout this iteration of the for-loop in "visitedneigh" and makes sure to not visit them. It takes steps to the original asset's neighbors, and choose one at random. It will set this next neighbor as the current asset, and depending on how high the risk level is, add this asset to "visitedneigh" and will take another step. Once our secondary for loop is done (the length of which is set by risklevel), it will assign whatever current asset we have accessed as the value for this key. Although a bit difficult to read, this is a subset of the output:



```
", \"Emerg Markets Bonds\"": "\"5/12/2015\", \"Corp Bond\"", "\"5/12/2015\", \"China Large Cap\"": "\"8/22/2014\", \"China Large Cap\"", "\"12/31/2014\", \"Cor
p Bond\"": "\"1/28/2016\", \"Pacific \"", "\"12/14/2015\", \"Yen\"": "\"8/31/2016\", \"China Large Cap\"", "\"12/14/2015\", \"Germany\"": "\"8/6/2015\", \"Fran
ce\"", "\"1/17/2014\", \"EAFE\"": "\"5/19/2017\", \"ST Corp Bond\"", "\"8/6/2015\", \"USD\"": "\"7/11/2014\", \"20+ Treasuries\"", "\"1/17/2014\", \"Emerg Mark
ets\"": "\"8/6/2015\", \"Europe\"", "\"8/22/2014\", \"Bonds Global\"": "\"5/19/2017\", \"Bonds II\"", "\"3/4/2014\", \"Gold Miners\"": "\"5/12/2015\", \"EAFE\"
"}
```

The key is before the semicolon and the value is after. However, it is important to remember that since these are calculated at random, this algorithm is a bit more unstable than the rest.

Tests



```
#[test]
fn test(){
    let testpath = r"C:\Users\dhanv\OneDrive\Desktop\2023-2024\Spring 24\DS 210\final_proj\final
    let (Assetstest, Nodestest) = read(testpath).expect("Couldn't Read!");
    let nt = Nodestest.len();
    let (testmap, testmat) = adjacent::createadj(Nodestest.clone(), 0.03, nt);
    let far_test = recommend(testmap.clone(), 1);
    let key = "\"2/13/2017\", \"Germany\"";
    let expvalue = "\"2/13/2017\", \"Pacifix ex Japan\"";
    match far_test.get(key){
        Some(value) => assert_eq!(value, expvalue),
        None => panic!("No key at all!")
    }
    let testgraph = Graph::new(nt, Nodestest.clone(), testmap.clone(), testmat.clone());
    let (testpos, testneg) = testgraph.dailyexpect(0.0);
    assert_eq!(testneg.iter().map(|(s, v)| (s.as_str(), *v)).collect::<Vec<_>>(),
    [("\"2/13/2017\", \"Commodities\"", -0.47149904489571054),
    ("\"2/13/2017\", \"Emerg Markets\"", -0.02977940328378424),
    ("\"2/13/2017\", \"Italy\"", -0.1748501500584068),
    ("\"2/13/2017\", \"France\"", -0.016355540693393806),
    ("\"2/13/2017\", \"UK\"", -0.08006145084453031)]);
    testgraph.portfolio();
    testgraph.groups()
}
```

This test looks like my main function to ensure there is no discrepancy in our final results. The only difference is that the test set is much smaller.

In order to test that my overall code works correctly, I extracted a small subset of this data into a testing csv file. It is only a few dates and a few assets so that I could compute the expected values by hand/excel and make sure my code works as expected. This is what my test data looks like (although it is also included in the github submission):

Date	Bonds Global	Commodities	DOW	Emerg Markets	EAFE	Emerg Markets Bonds	Pacifix ex Japan	Germany	Italy	Japan	France	UK
2/13/2017	79.46899	15.87	200.8181	38.16121	59.41037	109.2537	42.51091	26.90614	23.39388	51.25009	24.63444	31.29816

11/1/2013	73.04173	25.43	141.9465	39.31471	58.45649	91.67045	42.18145	26.30917	27.86369	44.45105	25.04066	33.90698

They are far apart in date to ensure that our log return differences vary for each asset we analyze.

Preliminary Manual Testing:

Since this subset of data was small, I calculated the log returns using a different excel sheet and found the following:

Date	Bonds Global	Commodities	DOW	Emerg Markets	EAFE	Emerg Markets Bonds	Pacifix ex Japan	Germany	Italy	Japan	France	UK
2/13/2017	0.08433596101	-0.4714990449	0.3469492972	-0.02977919442	0.01618607343	0.1754726198	0.007780197928	0.02243696574	-0.1748499578	0.1423287904	-0.01635543986	-0.08006158302
11/1/2013	0	0	0	0	0	0	0	0	0	0	0	0

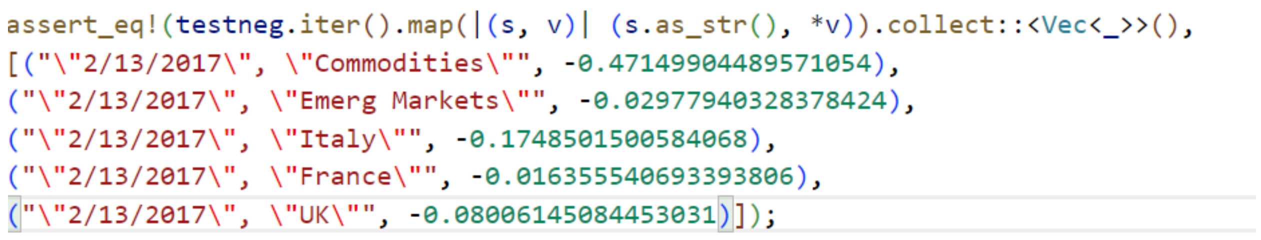
I also found the distance between each of these and found which ones would have edges based off of the maximum distance threshold in the code. This is what the output looks like (to make it simpler, the threshold is now 0.03 and the green values are less than the threshold)

	Bonds Global	Commodities	DOW	Emerg Markets	EAFE	Emerg Markets Bonds	Pacifix ex Japan	Germany	Italy	Japan	France	UK
Bonds Global	0	0.5558350059	0.2626133361	0.1141151554	0.06814988759	0.09113665879	0.07655576309	0.06189899528	0.2591859189	0.05799282937	0.1006914009	0.164397544
Commodities		0	0.818448342	0.4417198505	0.4876851183	0.6469716647	0.4792792428	0.4939360106	0.2966490871	0.6138278353	0.455143605	0.3914374619
DOW			0	0.3767284916	0.3307632237	0.1714766773	0.3391690992	0.3245123314	0.521799255	0.2046205068	0.363304737	0.4270108802

Emerg Markets				0	0.04596526785	0.20525181422	0.03755939235	0.05221616016	0.14507076344	0.17210798488	0.01342375456	0.05028238866
EAFE					0	0.20525181422	0.03755939235	0.05221616016	0.14507076344	0.17210798488	0.01342375456	0.05028238866
Emerg Markets Bonds						0	0.16769242199	0.15303565411	0.35032257766	0.033143829 42	0.19182805977	0.25553420288
Pacifix ex Japan							0	0.01465676781	0.18263015588	0.13454859255	0.02413563779	0.08784178095
Germany								0	0.19728692366	0.11989182477	0.03879240566	0.10249854888
Italy									0	0.31717874822	0.158494518	0.0947883743 82
Japan										0	0.15868423022	0.22239037344
France											0	0.06370614316
UK												0

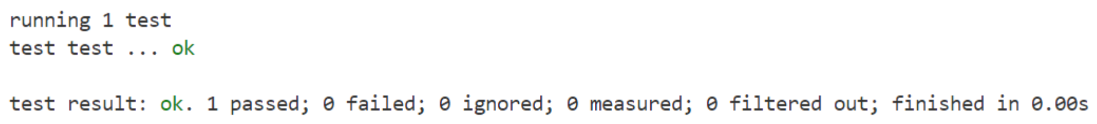
Test #1:

The first test primarily serves to see if the code properly reads the file, creates the graph, and calculates the log returns correctly. It builds off of the two lists we made before of positive and negative returns. Since there were only a few negative returns in this test data, I asserted that this should be the value of the entire “testneg” list (was able to find the values, differently rounded from our excel sheet, from the Nodes map and create this assertion).



```
assert_eq!(testneg.iter().map(|(s, v)| (s.as_str(), *v)).collect::<Vec<_>>(),
[("\"2/13/2017\", \"Commodities\"", -0.47149904489571054),
("\"2/13/2017\", \"Emerg Markets\"", -0.029779403283784 24),
("\"2/13/2017\", \"Italy\"", -0.1748501500584068),
("\"2/13/2017\", \"France\"", -0.016355540693393806),
("\"2/13/2017\", \"UK\"", -0.08006145084453031)]);
```

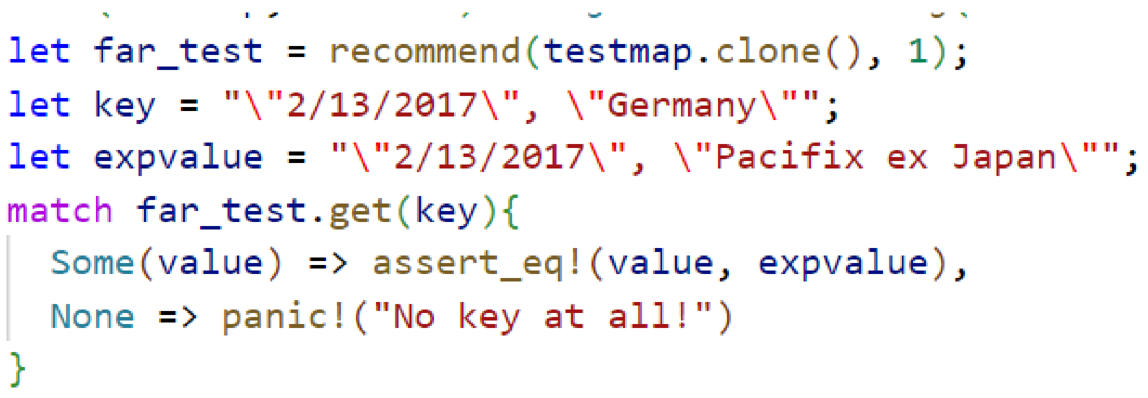
This test passed successfully:



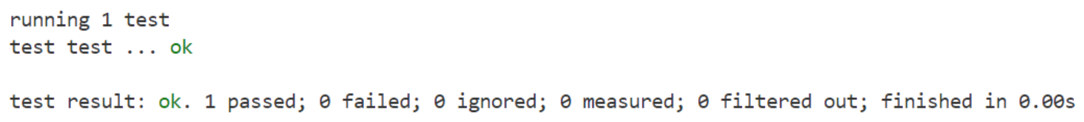
```
running 1 test
test test ... ok

test result: ok. 1 passed; 0 failed; 0 ignored; 0 measured; 0 filtered out; finished in 0.00s
```

Test #2:

My other test mostly tested if the pagerank style, recommend function, was working correctly and if edges were created correctly.



```
let far_test = recommend(testmap.clone(), 1);
let key = "\"2/13/2017\", \"Germany\"";
let expvalue = "\"2/13/2017\", \"Pacifix ex Japan\"";
match far_test.get(key){
    Some(value) => assert_eq!(value, expvalue),
    None => panic!("No key at all!")
}
```



```
running 1 test
test test ... ok

test result: ok. 1 passed; 0 failed; 0 ignored; 0 measured; 0 filtered out; finished in 0.00s
```

To make the test more simple, I picked the Germany value as it only has one edge. I asserted that the corresponding value in the hashmap for this key should be the Pacifix ex Japan asset. This test passed.

References

I used the following resources to iterate through my csv file:

https://doc.rust-lang.org/rust-by-example/flow_control/match.html

https://users.rust-lang.org/t/solved-how-to-fix-this-borrowed-value-does-not-live-long-enough/107105
https://users.rust-lang.org/t/how-to-get-first-column-from-library-rust-csv/4055/2

This for understanding graphs, nodes, and edges:
https://www.wsfcs.k12.nc.us/cms/lib/NC01001395/Centricity/Domain/1707/INTERATED%20unit04.pdf

These resources for helping with Git:
https://stackoverflow.com/questions/4181861/message-src-refspec-master-does-not-match-any-when-pushing-commits-in-git
https://stackoverflow.com/questions/16330404/how-to-remove-remote-origin-from-a-git-repository

These for understanding my dataset and calculating log returns:
https://gregorygundersen.com/blog/2022/02/06/log-returns/

This for understanding the logic behind BFS:
https://stackoverflow.com/questions/71189961/bfs-algorithm-tracking-the-path
https://stackoverflow.com/questions/13171038/how-to-find-the-distance-between-two-nodes-using-bfs
https://blog.logrocket.com/pathfinding-rust-tutorial-examples/

For component marking:
https://stackoverflow.com/questions/69010836/in-rust-how-can-i-create-a-function-which-will-accept-a-marker-component-as-a,
https://dev.to/fushji/a-weekly-rust-pill-5-5d5j
https://towardsdatascience.com/implementing-a-connected-component-labeling-algorithm-from-scratch-94e1636554f

https://chat.openai.com/share/071a1282-8577-4e9b-ac6e-5999b8f4155b
https://chat.openai.com/share/48d2b80b-0e7f-45f2-a1ca-e8fbfe23ae48
https://chat.openai.com/share/e186f4d5-8799-4772-aeee-aadf7c7066b7
https://chat.openai.com/share/1b3360f2-e5e7-497e-96dd-18896e177d3c