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College Football Rankings: Maximum Flow Model

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Maximum Flow Model

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Introduction

Football is America's favorite sport ("Football Reigns as America's Favorite Sport"). For some time now it has been the most watched sport in America, and that seems unlikely to change in the near future. While the National Football League (NFL) is the most popular sport, College Football comes in a close third behind another professional sport, Major League Baseball (MLB) (Rovell). Every Saturday most of the college football teams are tested with a tough battle. The big debate then comes that following week when the new rankings are put out. There is much debate over which team is better than another and how each one team compares to the rest of the nation. It is talked about on almost every sports talk show and across all offices in America. Everyone has their own opinion on why their team should be ranked in a certain position.

The old ranking system was the Bowl Championship Series (BCS). The BCS ranking system contained three elements, two human elements and one computer element. The two human elements it considers is the Harris Poll and the Coaches' Poll and the computer element is a calculation derived from six computer rankings ("BCS Formula"). There was a lot of controversy over the BCS ranking style and many people did not like the fact that there was a computer element in the rankings and the BCS era ended after the 2014 College Football Season.

A College Football Playoff was then founded to replace the BCS. A selection committee was formed with a group of influential individuals with various backgrounds. They would rank the top 25 teams and assign the top four teams that advance to the Playoff. During the BCS era many people believed there was a lot of bias towards the SEC from the computer rankings and that too much attention was being paid to just the winner and loser of the games, when there are other important variables that should be considered. A Committee that selects the top 25 teams and the top 4 teams that will be in the Playoff will also have some bias too. Some of the members of the committee have vested interest in certain schools and are alumni of the schools in the mix. Will this not cause them to have a slight edge for those teams? There is no way to get a completely bias-free ranking. The computer rankings will be slightly biased based on the creator and the committee will be slightly biased based on their previous experiences. If the committee was given a tool that could generate a ranking based on certain variables where weights can be adjusted, could this help them make a better decision?

After all there is a lot of money on the line when teams are selected to play in these big bowl games and have the potential to win the National Championship. College Football programs across the nation bring in a lot of money from media deals, tickets, and donations. It also brings in a surplus of money from attending post-season Bowl games. From the NCAA Revenues and Expenses Report the median generated revenue from the FBS in the 2014 fiscal year was $44,455,000 while the entire Division I without Football was only $2,667,000 (Fulks). Generated revenue is produced by the athletics department and includes ticket sales, radio and television receipts, alumni contributions, guarantees, royalties, NCAA distributions and other revenue sources that are not dependent upon institutional entities outside the athletics department. The difference between the amounts of revenue that football generates over the other Division I sports lends further evidence into why the college football-ranking problem is so important.

The Problem

There are 128 schools in the Division 1 Football Bowl Subdivision (FBS) of the National Collegiate Athletic Association (NCAA). That means there are over 8,128 possible matchup combinations between teams. During a college football season there are only about 869 games played, which is barley over 10% of the possible matchup combinations (Wiles). This means that teams are being compared to each other even though they did not get a chance to play on the field. One way to make such a comparison is by taking into account results against common opponents, opponents' opponents, and so on. Two teams may never have the chance to play each other, but do these types of connections suggest one team is better than the other?

CMS and CMS+

In order to rank the teams a quadratic assignment formulation was generated by Cassady, Maillart, and Salman. Let $i = 1, \dots, n$ denote teams and let $j = 1, \dots, n$ denote ranking positions. The formulation is given as:

$$\text{Maximize } \sum_{i=1}^{n}\sum_{i'=1}^{n}\sum_{j=1}^{n}\sum_{j'=1}^{n} f_{ii'}d_{jj'}x_{ij}x_{i'j'}, \tag{1a}$$

$$\text{subject to } \quad \sum_{j=1}^{n} x_{ij}, \qquad i = 1,2,\dots,n, \tag{1b}$$

$$\sum_{i=1}^{n} x_{ij}, \qquad j = 1,2,\dots,n, \tag{1c}$$

$$x_{ij} \in \{0,1\}, \qquad i = 1,2,\dots,n, j = 1,2,\dots,n, \tag{1d}$$

Where x_{ij} is a decision variable indicating whether ($x_{ij} = 1$) or not ($x_{ij} = 0$) team i is ranked in position j. Using this model the user must specify two sets of parameters: (1) $f_{ii'}$, the evidence that team i is superior to team i' (hereafter referred to as *evidence of superiority*) and (2) the *relative distance* $d_{jj'}$ between every pair of ranking positions j and j'. If team *i* defeats team i', then the degree of victory for team *i* over team i' is specified by the user. Throughout the history of this ranking system, the evidence of superiority has been computed in a number of ways: In the beginning *f* was initially only positive when team *i* played and beat team *i'*. A larger *f* value represented a more impressive victory. There was also a set multiplier for the game being a home victory, away victory, or a neutral site victory. A home victory had a value of 0.35, an away victory had a value of 0.65 and a neutral victory had a value of 0.5, meaning that away victories are more impressive than neutral or home victories. The *f* value was also multiplied by a date multiplier (DM) to incorporate more meaningful victories towards the end of the season. Games that were won on day 1 of the season were worth 60% of the games won on the last day of the season.

Computing relative distance was a problem in the first CMS model. The parameters and the distances produced did not have much meaning because the distance between 1 and 5 was not the same as the distance between 1 and 3 plus 3 and 5. So there was no meaning behind the distance relationship. Relative distance between position *j* and position j' is positive if position *j* is better than position j' and negative otherwise (Cassady et al. 2005). In order to create a better relationship in the distances the distance matrix was created. The distance matrix creates values between each ranking based on the following equation 2.

$$Z(i) = NormSInv\left(1 - \frac{i-0.5}{(n)}\right) \qquad i = 1 \dots n \qquad (2)$$

The distance matrix is then calculated using equation 3:

$$D(i, i') = Z(i) - Z(i') \qquad i = 1 \dots n \qquad (3)$$
$$i' = 1 \dots n$$

The distance matrix is then used in the fitness calculations that are discussed with detail later.

The next version of the ranking system was improved by Sullivan and Cassady who introduced the concept of transitive victories. If team A defeats team B and team B defeats team C then would it be reasonable to suggest that team A would defeat team C if they were to play? Since the teams do not actually play it would not be appropriate to give them a whole credit for the win, so a fraction of the credit, θ, is given to the team. This also helps make many more connections between teams that do not actually play each other. The addition of the transitive victory modifies the *f* value, degree of victory, giving teams fractional credit for transitive victories on top of their credit for their actual victories. The f value is the original *f* value where teams are given credit for head to head victories. The new *g* value, which used to be *f* in the previous iteration, is calculated as shown in equation 4:

$$f_{i,i'} = g_{i,i'} + \theta \left(\sum_{i''} g_{i'',i'} \right) \qquad (4)$$

Where θ, between 0 and 1, is a parameter value set by the user.

The most recent rendition to the CMS model was done by Wiles. Wiles added further improvements to the CMS+ model. Even though the transitive addition connected more pairs of teams, it still left many unconnected. It was discovered that during any particular football season the maximum number of links between any two teams was four. This led him to extend the transitive equation to add more degrees of separation so more pairs of teams can be connected. Since more degrees of separation were added the links between those teams would be farther apart so less credit would be awarded for the victory as the degree of separation got larger.

Wiles also added a component to the rankings that took into account a loss to a non-FBS team. A "dummy" team was incorporated to represent any non-FBS school. The dummy team would be present in the data set if an FBS school were to lose to a non-FBS team during the season. This "dummy" team would then be locked into the bottom spot so that it would not rise in the rankings. Another improvement made by Wiles was adding the factor of being conference champion to the rankings and also adding in the AP Poll ranking.

In this thesis a maximum flow network is implemented into the rankings in place of the transitive method used in these previous iterations.

Maximum Flow

Networks are all around us in every day life as telephones, cables, highways, rail, manufacturing, and sports. Maximum flow problems are used on these networks to determine the network's capacity for transmitting material from one node to another. Maximum flow problems contain problems that are modeled by a network in which the arcs may be thought of having a capacity that limits the quantity of the material that travels through the arc. The result of a maximum flow problem is to transport the maximum amount of flow from starting point (called the source) to a terminal point (called the sink) (Winston 1994).

In this thesis, we examine another way of computing $f_{ii'}$ in which we view the teams $i = 1 \ldots n$ as nodes $N = \{1 \ldots n\}$ and construct an arc set A by creating an arc (i, i') whenever $g_{ii'} > 0$ (i.e., whenever team i played and beat team i'). For arc $(i, i') \in A$, we define the capacity of arc (i, i') as $g_{ii'}$, and we compute $f_{ii'}$ for each $i, i' \in N$ as the maximum i–i' flow through the network $G = (N, A)$. This method is a maximum flow network.

Maximum flow provides a useful measure of superiority because it finds the maximum number of connections between every team and ranks the teams accordingly. To illustrate, suppose that for team *i* plays and defeats team *i'*, arc (*i, i'*) is constructed with capacity 1. In this case, the maximum flow from mode s to mode t equals the maximum number of disjoint "victory chains".

Solution Methods

Quadratic-assignment problems such as Model (1) are generally solved for solutions of problems of size n = 36 and n = 30, where in this case there n = 128 for the number of Division I-A college football teams (Serna, 2010). To account for this a heuristic solution procedure based on a genetic algorithm (GA) was used to identify a near-optimal solution. The GA uses parameter values for $\alpha_1, \alpha_2, \alpha_3, \beta_1, \beta_2$ that help compute relative distance and degree of victory based on many experiments.

The GA first randomly generates a user specified number of solution. The GA then computes the fitness of the solutions and discards a user specified percentage of the least fit solutions. The ranking that produces the best fitness is stored and used for comparison. For the next generations the solutions remaining from the previous generation serve as the initial population (parents). The GA then creates more solutions through either breeding or mutation, based on a user specified percentage. After creating this new generation it calculates the fitness and discards the percentage of least fit solutions again, and it continues to do this for a specified number of generations.

During the breeding process the GA produces new solutions by combining two random parent solutions to create a new, child, solution by comparing the parents characteristics. The parents are compared and any characteristics that match are passed down to the child solutions. Then the GA proceeds through the child's ranking from the top. If there is an open position, one of the parents rankings is chosen at random and the team in that position, if not already in the child's ranking, is put into the open position. If that team was already in the child's ranking then leave that position open and move to the next and repeat the process. Once the GA has tried to fill all of the open positions in the child, if there still remain open positions then a random parent is selected and all unassigned teams are places in the open positions in the child based on the order they appear in the parents. This will complete the child's ranking.

The mutation process only uses a single parent's rankings to produce a child. One parents is chosen at random and then two positions in the parents ranking is chosen at random. All of the teams between those two points are inverted and that is the new child. Mutation is mainly used so that the algorithm does not produce the same ranking repetitively and conform to a local optimal.

The second phase of the heuristic is the use of a pairwise switching algorithm. The switching algorithm is used to improve on the best rankings solution from the breeding and mutation. The switching algorithm starts with the best fitness rankings from the step before and begins to switch pairs of teams starting with 1 and 2, 1 and 3, 1 and 4, and so on until it gets to 1 and 125. The algorithm then moves on to the next positions and switches 2 and 3, 2 and 4 and so on until every possible switch has been made. After each switch the fitness of the potential new solution is calculated and if that switch improves the fitness that switch is made and the switching algorithm starts over. If the switch does not improve the fitness then the teams are returned to their original positions and the algorithm moves to the next switch. The switching algorithm continues until all the switches are made and the fitness of the ranking does not improve.

Since the first step of the GA is to randomly produce a number of solutions, the entire process is repeated for a user specified amount of times to help level out the randomness of the solutions produced. Once all the iterations are complete the ranking with the best fitness value is the final ranking.

The Fitness is calculated as in Equation 5:

$$Fitness = Fitness + f[i, i'] * DM\left[ranking[i], ranking[i']\right] \tag{5}$$

The fitness is calculated for each ranking that is generated, if that rankings fitness is greater than the original fitness then that ranking is kept until rankings fitness is greater than that. Once the highest fitness is found the rankings for that fitness are outputted as that breeds ranking.

This process is performed exactly the same by Wiles (2013) using the same five parameters. Parameter α_1 is the percentage of the total points that are assigned to head-to-head victories. Parameter α_2 is the percentage of the remaining points that are assigned to indirect victories. Parameter α_3 is the percentage of the remaining points that are assigned to conference champions and all remaining points are assigned to the teams relative rankings in the AP Poll. Parameter β_1 is the percentage of the last day of the season that the first day will be worth.

Parameter β_2 is the percentage of away games that home games are worth, with neutral site victories falling hallway between β_2 and 1. Only $\alpha_1, \alpha_2, \beta_1,\ and\ \beta_2$ are used in this approach. . Parameter α_3 was not used because including a certain percentage for the conference champion did not seem necessary in analyzing how the maximum flow network worked in place for the transitive network, so to keep all runs consistent α_3 was 0 for all runs.

Experimentation

In order to test how well the maximum flow network would work in the rankings network a series of test were performed with the maximum flow network and with the transitive network. Since the rankings still contain the five different input variables $\alpha_1, \alpha_2, \alpha_3, \beta_1, \beta_2$, different values were assigned to each variable to test the differences in the rankings. The values we used for each parameter are in the table below.

$I.$ 1) $\alpha_1 = 1, \alpha_2 = 0$ 2) $\alpha_1 = 0.5, \alpha_2 = 0.5$ 3) $\alpha_1 = 0.75, \alpha_2 = 0.25$ 4) $\alpha_1 = 0.25, \alpha_2 = 0.75$	$II.$ 1) $\beta_1 = 0.5$ 2) $\beta_1 = 0.25$ 3) $\beta_1 = 0.75$	$III.$ 1) $\beta_2 = 1$ 2) $\beta_2 = 0.75$ 3) $\beta_2 = 0.25$

These values were chosen because it was necessary to test a variety of parameters to analyze how the two different approaches, maximum flow and transitive, reacted to the different parameter values. The experiments were then batched together and run in groups:

Run 1	(1, 1, 1)	Run 5	(1, 2, 1)	Run 9	(1, 3, 1)	Run 13	(1, 1, 2)	Run 17	(1, 1, 3)
Run 2	(2, 1, 1)	Run 6	(2, 2, 1)	Run 10	(2, 3, 1)	Run 14	(2, 1, 2)	Run 18	(2, 1, 3)
Run 3	(3, 1, 1)	Run 7	(3, 2, 1)	Run 11	(3, 3, 1)	Run 15	(3, 1, 2)	Run 19	(3, 1, 3)
Run 4	(4, 1, 1)	Run 8	(4, 2, 1)	Run 12	(4, 3, 1)	Run 16	(4, 1, 2)	Run 20	(4, 1, 3)

Each number in a run corresponds to the number in the list of parameters shown earlier to identify what the parameters are for each run. The first number is from section I, the second number is from section II, and the third number is from section III. For example Run 1 has (1,1,1) meaning that its parameters are $\alpha_1 = 1, \alpha_2 = 0, \beta_1 = 0.5, \text{and } \beta_2 = 1$.

Note that when $\alpha_1 = 1$, we use the maximum flow $f_{i,i'}$ values and otherwise use Sullivan/Wiles transitivity. Thus, Run 1, Run 5, Run 9, Run 13, and Run 17 are all rankings generated using the maximum flow network.

Results

It was discovered that the fitness calculation could not be used to compare a maximum flow ranking to a transitive ranking because their fitness calculations are performed differently. For the transitive method the $\bar{h}_{i,i'}, h_{i,i'}$ is caluculated the same way as it was mentioned in Wiles 2013. The resulting *f* was calculated from equation 6.

$$f_{i,i'} = f_{i,i'} + h_{i,i'} \tag{6}$$

The maximum flow calculations are slightly different which makes the fitness calculations incomparable for the two different methods. For the maximum flow method $\bar{h}_{i,i'}$ is the maximum flow value between team *i* and team *i'*. *f* is then calculated using equation 7:

$$f_{i,i'} = \frac{\bar{h}_{i,i'}}{\bar{h}_{max}} \qquad (7)$$

Rankings would be compared using two different methods anomalies and violations. An anomaly occurs, for this experiment, whenever a team's ratio between its maximum flow ranking and it's Coaches Poll rankings is greater than 2 or less than ½. By defining an anomaly in this context, we can say that it is out of position in the rankings we generated if it is not within this range in the Coaches Poll rankings.

In previous iterations of the CMS rankings the ratio between the CMS rankings and the BCS poll were used to define an anomaly. In this case the Coaches Poll is used because since 2014 the BCS has been replaced with the College Football Playoff. With this transition comparing the new rankings to the BCS rankings did not seem appropriate, because the BCS has been removed and does not seem likely to come back. The Coaches poll is voted on by 62 coaches that are selected at random at the beginning of the season. This poll seemed to be the best poll to compare our rankings too because, in a way, is similar to a committee that ranks the best teams week to week. It is not our goal to be able to match what the Coaches poll is able to produce or any other poll for that matter, but it serves as a good measure of how well our rankings are compared to what the Coaches believe the rankings are. There is some bias in the Coaches Poll because some coaches have a tendency to vote more in favor of their team and in some cases in their own conference, but every poll has some bias and it is too their own integrity they rank the teams.

The second method that was used to analyze the rankings was violations. A violation in this context is defined as the instance where a team *i* is ranked better than team *i'* but team *i'* played and defeated team *i*. This gives visibility in the rankings where even though there was some head to head games lost, the rankings still found a reason to rank the losing team of the head to head matchup higher then the winning team. This would be more evident where head to head matchups have lower parameter.

5 years of data, years 2013, 2011, 2010, 2009, and 2008, were run for the 20 different tests.

The results from the tests as shown in Tables 1 – 7 and Figures 1 – 2 below:

Table 1: Anomalies

Run	2013	2011	2010	2009	2008	Average
1	2	5	0	2	4	3
2	0	0	0	0	0	0
3	0	0	0	0	0	0
4	0	0	1	0	0	0
5	3	3	0	6	6	4
6	0	0	0	0	0	0
7	0	0	0	0	0	0
8	0	0	1	0	0	0
9	2	6	0	2	4	3
10	0	0	0	0	0	0
11	0	0	0	0	0	0
12	0	0	1	0	0	0
13	2	5	0	1	4	2
14	0	0	0	0	0	0
15	0	0	0	0	0	0
16	0	0	1	0	0	0
17	2	5	0	1	4	2
18	0	0	0	0	0	0
19	0	0	0	0	0	0
20	0	0	1	0	0	0

Table 2: Violations

Run	2013	2011	2010	2009	2008	Average
1	161	123	130	123	138	135
2	140	118	138	119	135	130
3	144	118	147	123	136	134
4	146	117	133	118	129	129
5	166	127	134	124	140	138
6	145	118	136	123	135	131
7	147	121	147	128	138	136
8	147	118	132	119	135	130
9	160	120	130	124	137	134
10	143	121	135	117	135	130
11	143	121	145	120	136	133
12	148	115	132	116	128	128
13	161	121	133	128	134	135
14	140	115	134	116	131	127
15	142	123	142	123	135	133
16	148	114	132	119	127	128
17	158	116	131	130	126	132
18	144	115	133	116	131	128
19	139	124	140	119	135	131
20	148	115	130	118	128	128

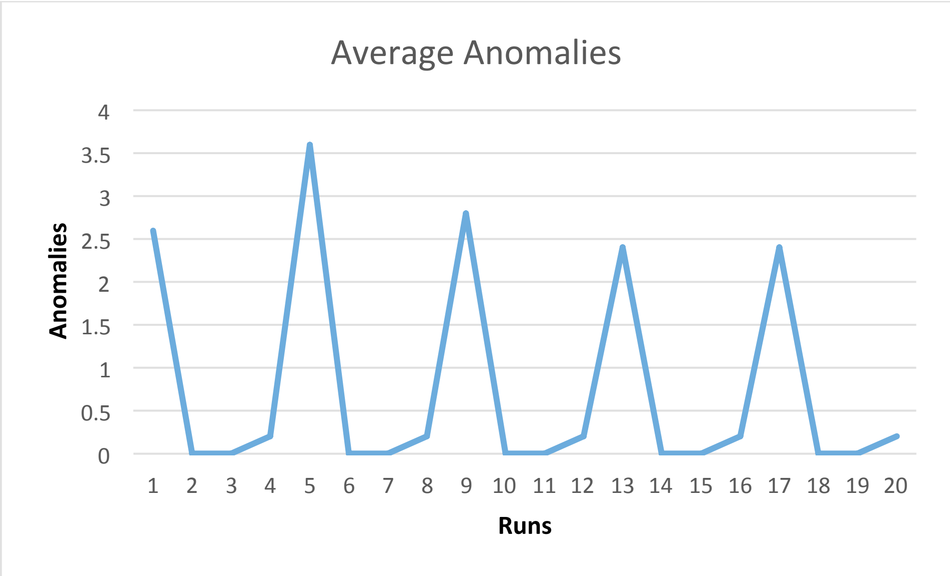

Figure 1: Average Anomalies

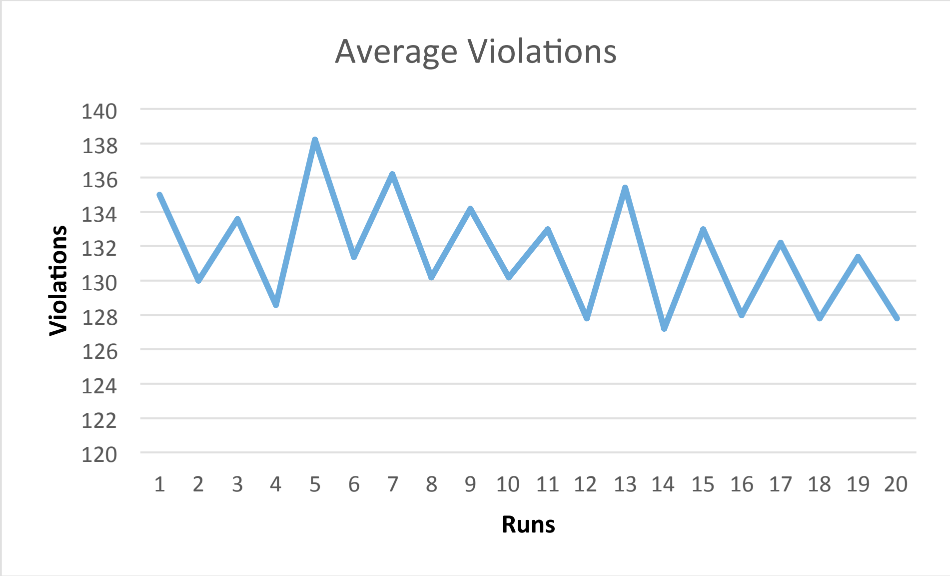

Figure 2: Average Violations

Table 3: 2013 Anomalies

Team	Coach's Poll Rank	Run 1 Rank	Run 5 Rank	Run 9 Rank	Run 13 Rank	Run 17 Rank
FloridaState	1	1	1	1	1	1
Auburn	2	2	2	2	2	2
Alabama	3	3	3	3	3	3
MichiganState	4	5	5	5	4	4
Baylor	5	4	6	4	5	6
OhioState	6	7	11	6	6	5
Stanford	7	10	8	11	11	9
SouthCarolina	8	12	10	15	12	11
Missouri	9	9	4	10	9	10
Oklahoma	10	13	13	14	13	15

Table 4: 2011 Anomalies

Team	Coach's Poll Rank	Run 1 Rank	Run 5 Rank	Run 9 Rank	Run 13 Rank	Run 17 Rank
LouisianaState	1	1	1	1	1	1
Alabama	2	2	2	2	2	2
OklahomaState	3	4	3	4	4	4
Stanford	4	5	5	5	5	6
Oregon	5	6	7	7	7	7
BoiseState	6	14	22	13	13	12
Arkansas	7	3	4	3	3	3
Wisconsin	8	17	15	20	18	19
SouthCarolina	9	16	13	14	15	14
KansasState	10	8	8	6	6	5

Table 5: 2010 Anomalies

Team	Coach's Poll Rank	Run 1 Rank	Run 5 Rank	Run 9 Rank	Run 13 Rank	Run 17 Rank
Oregon	1	2	2	2	2	2
Auburn	2	1	1	1	1	1
TexasChristian	3	4	4	4	4	4
Wisconsin	4	7	8	8	7	6
Stanford	5	3	3	3	3	3
OhioState	6	6	7	7	6	7
MichiganState	7	10	9	9	10	11
Arkansas	8	5	5	5	5	5
Oklahoma	9	17	15	17	17	17
BoiseState	10	11	13	11	11	10

Table 6: 2009 Anomalies

Team	Coach's Poll Rank	Run 1 Rank	Run 5 Rank	Run 9 Rank	Run 13 Rank	Run 17 Rank
Alabama	1	1	2	1	1	1
Texas	2	6	6	4	4	4
TexasChristian	3	5	4	5	5	5
Cincinnati	4	2	1	3	2	2
Florida	5	3	3	2	3	3
BoiseState	6	4	5	6	6	6
Oregon	7	7	7	7	7	7
OhioState	8	16	24	14	16	14
PennState	9	22	39	20	22	19
GeorgiaTech	10	15	17	15	14	10

Table 7: 2008 Anomalies

Team	Coach's Poll Rank	Run 1 Rank	Run 5 Rank	Run 9 Rank	Run 13 Rank	Run 17 Rank
Oklahoma	1	1	2	1	1	1
Florida	2	14	20	14	12	12
Texas	3	2	1	2	2	2
Alabama	4	12	13	12	13	13
SouthernCalifornia	5	10	11	10	9	9
PennState	6	9	8	9	10	11
Utah	7	3	4	3	3	3
TexasTech	8	4	3	4	4	4
BoiseState	9	5	5	5	5	5
OhioState	10	15	12	17	16	15

Analysis

From the results of the rankings, it is clear that the maximum flow characteristic of the rankings does cause some fluctuations from the Coaches poll rankings, but that is not necessarily a bad thing.

From the results doing the anomalies test, all but 5 of the runs that used the Sullivan/Wiles transitive method did not have any anomalies based on our definition, and the ones that did have an anomaly, it was only one anomaly and it was in between the 20th and 25th ranked teams. This lets us know that even with different parameters used for the transitive method the rankings were still similar in comparison to the Coaches Poll and did not vary too much. On the other hand there were some notable anomalies from the maximum flow rankings, which can be seen in the Tables 3, 4, 5, 6, and 7 above. The maximum flow rankings from the years 2013 and 2010 did not have any anomalies in the top 10 positions of the Coaches poll rankings, while year's 2011, 2009, and 2008 have a few significant anomalies. In the 2011 maximum flow rankings the 6th, 7th, and 8th ranking positions had all of the differences. Boise State who was ranked 6th in the Coaches Poll and around the same position in other polls were not getting that kind of credit in the maximum flow rankings. During that year they only played two ranked opponents Georgia, who they defeated in the first game of the year, and TCU, who they lost too and who beat them out for the title of conference champion. All of their other wins were against lower quality teams most of which did not have winning records. This could be the reason they did not have many connections to teams they did not play because their competition was not very good. On the other hand Arkansas who was ranked 7th in the Coaches Poll was ranked 3rd in most of the maximum flow rankings. The reason being the exact opposite of Boise State, in that the only two losses Arkansas had were to Louisiana State and Alabama who were both ranked 1st and 2nd in all of the polls. Their strength of schedule and "quality losses" lead to more connections by the maximum flow network and caused them to be ranked higher.

In the 2009 rankings the position of Penn State caused the most questions. They were ranked 9th in the Coaches Poll but in the maximum flow rankings they were mainly around 20th and even at 39th in one ranking. The reason for this seems to be the same reason Boise State didn't rank very high in the maximum flow rankings in the 2011 season. Penn State played two ranked opponents, Iowa and Ohio State, and they lost both of those games. They finished 3rd in the Big Ten coming behind both the teams they lost to and they did not even play Wisconsin who finished 4th in the conference.

The maximum flow rankings from the 2008 season were very interesting. Florida ranked 2nd in the Coaches Poll was not ranked higher than 12th and in one ranking, ranked 20th, in the maximum flow rankings. Alabama was ranked 4th in the Coaches Poll but they also were around the 13th spot in the maximum flow rankings. Looking back on the 2008 season, the SEC was having a down year while the Big 12 was very strong. The teams in the SEC besides Alabama and Florida were all middle of the pack teams, with only three other teams having more than a one game winning record. That did not help Florida and Alabama in the maximum flow network as they did not have as many connections to other teams in college football. While in the Big 12 Texas, Oklahoma, and Texas Tech all only had one lose on the season all to each other. First Texas defeated Oklahoma early in the season. Texas Tech then defeated Texas a few weeks later and then Oklahoma defeated Texas Tech in the second to last game of the season. This gave Oklahoma the advantage over Texas Tech and Texas in most of the maximum flow rankings. In Run 5 the B1 parameter in lowered, giving more equal weight on a win no matter if it is earlier in the season or later, so in this rankings Texas was actually ranked 1st while Oklahoma and Texas Tech were ranked 2nd and 3rd respectively.

The violations test tells a slightly different story than the anomalies. The violations were calculated for all teams in the rankings, not only the top 25. There is not very much difference in the violations between transitive rankings and maximum flow rankings. From the graph of average violations, in Figure 2, it can be seen that there is no direct relation between the different parameters and the number of violations. Most of the violations that occurred were for teams that were outside of the top 25, were the rankings tend not to matter as much. Run 5, a maximum flow ranking, had on average the most violations. Its parameters gave not as much weight to the games won towards the end of the season as the beginning and that could be a reason why more violations occurred. The runs that had lower α_1, parameter on head-to-head games, had the lowest number of violations. This was expected because where the weight on head to head games was lower teams were ranked higher based on their connections with other teams rather than their head to head performance.

Conclusions and Future Work

Incorporating the maximum flow network into the CMS+ ranking system doesn't seem to improve the overall quality of the ranking based on the anomalies, but it does not necessarily make that a bad thing. The maximum flow network allows for more observations between different teams to be made rather than the CMS+ which only looks as far as 4 degrees of separation. This leads to more differences in the rankings because they are able to find much deeper connections between that a simple analysis cannot pickup. With the addition of the maximum flow network paired with the parameters that were already in the CMS+ rankings it allows the user to look at a possible solution of the rankings where all the possible paths between two teams has been found and compared.

In the future more parameters can be added to the rankings to help justify why one team should rank higher than another. These parameters can be more traditional such as what the team's power index rankings or strength of schedule is, or less traditional in weather conditions or how long the winner held the lead. These extra parameters can lead to better descriptions of what actually took place in the game and not just what the final score was. This is important because there is a lot of stress being put on rankings teams not solely on wins and losses but also by an "eye test". The maximum flow network is great for connecting paths between teams but there is much more to ranking teams than just their wins and losses.

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