The Bowl Championship Series: A Mathematical Review

Thomas Callaghan, Peter J. Mucha, and Mason A. Porter

Introduction

On February 29, 2004, the college football Bowl Championship Series (BCS) announced a proposal to add a fifth game to the "BCS bowls" to improve access for midmajor teams ordinarily denied invitations to these lucrative postseason games. Although still subject to final approval, this agreement is expected to be instituted with the new BCS contract just prior to the 2006 season.

There aren't too many ways that things could have gone worse this past college football season with the BCS Standings governing which teams play in the coveted BCS bowls. The controversy over USC's absence from the BCS National Championship game, despite being #1 in both polls, garnered most of the media attention [12], but it is the yearly treatment received by the "non-BCS" midmajor schools that appears to have finally generated changes in the BCS system [15].

Created from an abstruse combination of polls, computer rankings, schedule strength, and quality wins, the BCS Standings befuddle most fans and sportswriters, as we repeatedly get "national championship" games between purported "#1" and "#2" teams in disagreement with the polls' consensus. Meanwhile, the top non-BCS squads have never been invited to a BCS bowl. Predictably, some have placed blame for such predicaments squarely on the "computer nerds" whose ranking algorithms form part of the BCS formula [7], [14]. Although we have no part in the BCS system and the moniker may be accurate in our personal cases, we provide here a mathematically inclined review of the BCS. We briefly discuss its individual components, compare it with a simple algorithm defined by random walks on a biased graph, attempt to predict whether the proposed changes will truly lead to increased BCS bowl access for non-BCS schools, and conclude by arguing that the true problem with the BCS Standings lies not in the computer algorithms but rather in misguided addition.

Motivation for the BCS

The National Collegiate Athletic Association (NCAA) neither conducts a national championship in Division I-A football nor is directly involved in the current selection process. For decades, teams were selected for major bowl games according to traditional conference pairings. For example, the Rose Bowl featured the conference champions from the Big Ten and Pac-10. Consequently, a match between the #1 and #2 teams in the nation rarely occurred. This frequently left multiple undefeated teams and cochampions—most recently Michigan and Nebraska in 1997. It was also possible for a team with an easier schedule to go undefeated without having played a truly "major" opponent and be declared champion by the polls, though the last two schools outside the current BCS agreement to do so were BYU in 1984 and Army in 1945.

The BCS agreement, forged between the six major "BCS" conferences (the Pac-10, Big 12, Big

---

Thomas Callaghan is an undergraduate majoring in applied mathematics, Peter Mucha is assistant professor of mathematics, and Mason Porter is a VIGRE visiting assistant professor, all at Georgia Institute of Technology. Peter Mucha's email address is `mucha@math.gatech.edu`. *This work was partially supported by NSF VIGRE grant DMS-0135290 as a Research Experiences for Undergraduate project and by a Georgia Tech Presidential Undergraduate Research Award.* *The simulated monkeys described herein do not know that they live on Georgia Tech computers. No actual monkeys were harmed in the course of this investigation.*

Ten, ACC, SEC, and Big East, plus Notre Dame as an independent), was instituted in 1998 in an attempt to fix such problems by matching the top two NCAA Division I-A teams in an end-of-season BCS National Championship game. The BCS Standings, tabulated by The National Football Foundation [18], selects the champions of the BCS conferences plus two at-large teams to play in four end-of-season "BCS bowl games", with the top two teams playing in a National Championship game that rotates among those bowls. Those four bowl games—Fiesta, Orange, Rose, and Sugar—generate more than $100 million annually for the six BCS conferences, but less than 10 percent of this windfall trickles down to the other five (non-BCS) Division I-A conferences [13]. With the current system guaranteeing a BCS bowl bid to a non-BCS school only if that school finishes in the top 6 in the Standings, those conferences have complained that their barrier to appearing in a BCS bowl is unfairly high [20]. Moreover, the money directly generated by the BCS bowls is only one piece of the proverbial pie, as the schools that appear in such high-profile games receive marked increases in both donations and applications.

Born from a desire to avoid controversy, the short history of the BCS has been anything but uncontroversial. In 2002 precisely two major teams (Miami and Ohio State) went undefeated during the regular season, so it was natural for them to play each other for the championship. In 2000, 2001, and 2003, however, three or four teams each year were arguably worthy of claiming one of the two invites to the championship game. Meanwhile, none of the non-BCS schools have ever been invited to play in a BCS bowl. Tulane went undefeated in 1998 but finished 10th in the BCS Standings. Similarly, Marshall went undefeated in 1999 but finished 12th in the BCS. In 2003, with no undefeated teams and six one-loss teams, the three BCS one-loss teams (Oklahoma, LSU, and USC) finished 1st through 3rd (respectively) in the BCS Standings, whereas the three non-BCS one-loss teams finished 11th (Miami of Ohio), 17th (Boise State), and 18th (TCU).

The fundamental difficulty in accurately ranking or even agreeing on a system of ranking the Division I-A college football teams lies in two factors: the paucity of games played by each team and the large disparities in the strength of individual schedules. With 117 Division I-A football teams, the 10–13 regular season games (including conference tournaments) played by each team severely limits the quantity of information relative to, for example, college and professional basketball and baseball schedules. While the 32 teams in the professional National Football League (NFL) each play 16 regular season games against 13 distinct opponents, the NFL subsequently uses regular season outcomes to seed a 12-team playoff. Indeed, Division I-A college football is one of the only levels of any sport that does not currently determine its champion via a multigame playoff format.[1] Ranking teams is further complicated by the Division I-A conference structure, as teams play most of their games within their own conferences, which vary significantly in their level of play. To make matters worse, even the notion of "top 2" teams is woefully nebulous: Should these be the two teams who had the best aggregate season or those playing best at the end of the season?

The BCS Formula and Its Components

In the past, national champions were selected by polls, which have been absorbed as one component of the BCS formula. However, they have been accused of bias towards the traditional football powers and of making only conservative changes among teams that repeatedly win. In attempts to provide unbiased rankings, many different systems have been promoted by mathematically and statistically inclined fans. A subset of these algorithms comprise the second component of the official BCS Standings. Many of these schemes are sufficiently complicated mathematically that it is virtually impossible for lay sports enthusiasts to understand them. Worse still, the essential ingredients of some of the algorithms currently used by the BCS are not publicly declared. This state of affairs has inspired the creation of software to develop one's own rankings using a collection of polls and algorithms [21] and comical commentary on "faking" one's own mathematical algorithm [11].

Let's break down the cause of all this confusion. The BCS Standings are created from a sum of four numbers: polls, computer rankings, a strength of schedule multiplier, and the number of losses by each team. Bonus points for "quality wins" are also awarded for victories against highly ranked teams. The smaller the resulting sum for a given team, the higher that team will be ranked in the BCS Standings.

The first number in the sum is the mean ranking earned by a team in the AP Sportswriters Poll and the *USA Today*/ESPN Coaches Poll.

The second factor is an average of computer rankings. Seven sources currently provide the algorithms selected by the BCS. The lowest computer ranking of each team is removed, and the remaining six are averaged. The sources of the participating ranking systems have changed over the short history of the system, most recently when the BCS mandated that the official computer ranking

[1] *The absence of a Division I-A playoff is itself quite controversial, but we do not intend to address this issue here. Rather, we are more immediately interested in possible solutions under the constraint of the NCAA mandate against playoffs.*

Simple Random Walker Rankings

Consider independent random walkers who each cast a single vote for the team they believe is the best. Each walker occasionally considers changing its vote by examining the outcome of a single game selected randomly from those played by their favorite team, recasting its vote for the winner of that game with probability p (and for the loser with probability $1 - p$). In selecting $p \in (1/2, 1)$ to be the only parameter of this simple ranking system, we explicitly ignore margin of victory (currently forbidden in official BCS systems) and other potentially pertinent pieces of information (including the dates that games are played).

We denote the number of games team i played by n_i, the number it won by w_i, and the number it lost by l_i. A tie (not possible with the current NCAA overtime format) is counted as both half a win and half a loss, so that $n_i = w_i + l_i$. We denote the number of random walkers casting their single vote for team i as v_i.

To avoid rewarding teams for the number of games played, we set the rate at which a walker voting for team i decides to recast its vote to be proportional to n_i (with those games then selected uniformly). In other words, the rate that a single game played by team i is considered by a walker at site i (e.g., by a Poisson process) is independent of the other games played by team i. Both because of this rate definition and to circumvent cycles that can arise in discrete-time transition problems, we find it convenient to consider the statistics of the random walkers in terms of differential equations for the expected populations.

For a game in which team i beats team j, the average rate at which a walker voting for j changes to i is proportional to $p > \frac{1}{2}$ (as it is more likely that the winning team is actually the better team), and the rate at which a walker already voting for i switches to j is proportional to $(1 - p)$. The expected rates of change of the populations at each site are thus described by a homogeneous system of linear differential equations,

$$\bar{\mathbf{v}}' = \mathbf{D} \cdot \bar{\mathbf{v}}, \tag{1}$$

where $\bar{\mathbf{v}}$ is the T-vector of the expected number $\bar{v}_i$ of votes cast for each of the T teams, and $\mathbf{D}$ is the square matrix with components

$$\begin{aligned} D_{ii} &= -pl_i - (1-p)w_i, \\ D_{ij} &= \frac{1}{2}N_{ij} + \frac{(2p-1)}{2}A_{ij}, \quad i \neq j, \end{aligned} \tag{2}$$

where $N_{ij} = N_{ji}$ is the number of head-to-head games played between teams i and j, and $A_{ij} = -A_{ji}$ is the number of times team i beat team j minus the number of times team i lost to team j in those N_{ij} games. In particular, if i and j played no more than a single head-to-head game,

$$\begin{aligned} A_{ij} &= +1, \quad \text{if team } i \text{ beat team } j, \\ A_{ij} &= -1, \quad \text{if team } i \text{ lost to team } j, \\ A_{ij} &= 0, \quad \text{if team } i \text{ tied or did not play team } j. \end{aligned} \tag{3}$$

If two teams play each other multiple times (which can occur because of conference championships), we sum the contribution to A_{ij} from each game. This multiplicity also occurred in the calculations we performed, because we treated all non-Division I-A teams as a single team (which is, naturally, ranked lower than almost all of the 117 Division I-A teams).

The matrix $\mathbf{D}$ encompasses all the win-loss outcomes between teams. The off-diagonal elements D_{ij} are nonnegative, vanishing only for teams i and j that did not play directly against one another (because $p < 1$). The steady-state equilibrium $\bar{\mathbf{v}}^*$ of (1) and (2) satisfies

$$\mathbf{D} \cdot \bar{\mathbf{v}}^* = \mathbf{0}, \tag{4}$$

lying in the null-space of $\mathbf{D}$; that is, $\bar{\mathbf{v}}^*$ is an eigenvector associated with a zero eigenvalue. As long as the graph of teams connected by their games played comprises a single connected component, then the matrix must have codimension one for $p < 1$ and $\bar{\mathbf{v}}^*$ is unique up to a scalar multiple. We therefore restrict the probability p of voting for the winner to the interval $(\frac{1}{2}, 1)$; the winning team is rewarded for winning, but some uncertainty in voter behavior is maintained. The distribution of $\mathbf{v}$ is then joint binomial with expectation $\bar{\mathbf{v}}^*$, and the expected populations of each site yield a rank ordering of the teams.

Although this random walker ranking system is grossly simplistic, we have found [3], [4] that this algorithm does a remarkably good job of ranking college football teams, or at least arguably as good as the other available systems. In the absence of sufficient detail to reproduce the official BCS computer rankings, we use this simple random walker ranking scheme here to analyze the effects of possible changes to the BCS.

algorithms were not allowed to use margin of victory starting with the 2002 season. In the two seasons since that change, the seven official systems have been provided by Anderson & Hester, Billingsley, Colley, Massey, *The New York Times*, Sagarin, and Wolfe. None of these sources receive any compensation for their time and effort; indeed, many of them appear to be motivated purely out of a combined love of football and mathematics. Nevertheless, the creators of most of these systems guard their intellectual property closely. An exception is Colley's ranking, which is completely defined on his website [5]. Billingsley [1], Massey [17], and Wolfe [23] provide significant information about the ingredients for their rankings, but it is insufficient to reproduce their analysis. Additional information about the BCS computer ranking algorithms (and numerous other ranking systems) can be found on David Wilson's website [22].

The third component of the BCS formula is a measurement of each team's schedule strength. Specifically, the BCS uses a variation of what is commonly known in sports as the Ratings Percentage Index (RPI), which is employed in college basketball and college hockey to help seed their end-of-season playoffs. In the BCS, the average winning percentage of each team's opponents is multiplied by $2/3$ and added to $1/3$ times the winning percentage of its opponents' opponents. This schedule strength is used to assign a rank to each team, with 1 assigned to that deemed most difficult. That rank ordering is then divided by 25 to give the "Schedule Rank", the third additive component of the BCS formula.

The fourth additive factor of the BCS sum is the total number of losses by each team.

Once these four numbers (polls, computers, schedule strength, and losses) are summed, a final quantity for "quality wins" is subtracted to account for victories against top teams. The current reward is –1.0 points for beating the #1 team, decreasing in magnitude in steps of 0.1, down to –0.1 points for beating the #10 team.

It is not difficult to imagine that small changes in any of the above weightings have the potential to alter the BCS Standings dramatically. However, because of the large number of parameters, including unknown "hidden parameters" in the minds of poll voters and the algorithms of computers, any attempt to exhaustively survey possible changes to the rankings is hopeless. Instead, to demonstrate how weighting different factors can influence the rankings, we discuss a simple ranking algorithm in terms of random walkers on a biased network.

Ranking Football Teams with Random Walkers

Before introducing yet another ranking algorithm, we emphasize that numerous schemes are available for ranking teams in all sports. See, for example, [6], [10], and [16] for reviews of different ranking methodologies and the listing and bibliography maintained online by David Wilson [22].

Instead of attempting to incorporate every conceivable factor that might determine a team's quality, we took a minimalist approach, questioning whether an exceptionally naive algorithm can provide reasonable rankings. We consider a collection of random walkers who each cast a single vote for the team they believe is the best. Their behavior is defined so simplistically (see sidebar) that it is reasonable to think of them as a collection of trained monkeys. Because the most natural arguments concerning the relative ranking of two teams arise from the outcome of head-to-head competition, each monkey routinely examines the outcome of a single game played by their favorite team—selected at random from that team's schedule—and determines its new vote based entirely on the outcome of that game, preferring but not absolutely certain to go with the winner.

In the simplest definition of this process, the probability p of choosing the winner is the same for all voters and games played, with $p > 1/2$, because on average the winner should be the better team, and $p < 1$ to allow a simulated monkey to argue that the losing team is still the better team (due perhaps to weather, officiating, injuries, luck, or the phase of the moon). The behavior of each virtual monkey is driven by a simplified version of the "but my team beat your team" arguments one commonly hears. For example, much of the 2001 BCS controversy centered on the fact that BCS #2 Nebraska lost to BCS #3 Colorado, and the 2000 BCS controversy was driven by BCS #4 Washington's defeat of BCS #3 Miami and Miami's win over BCS #2 Florida State.

The synthetic monkeys act as independent random walkers on a graph with biased edges between teams that played head-to-head games, changing teams along an edge based on the win-loss outcome of that game. The random behavior of these individual voters is, of course, grossly simplistic. Indeed, under the specified range of p, a given voter will never reach a certain conclusion about which team is the best; rather, it will forever change its allegiance from one team to another, ultimately traversing the entire graph. In practice, however, the macroscopic total of votes cast for each team by an aggregate of random-walking voters quickly reaches a statistically steady ranking of the top teams according to the quality of their seasons.

We propose this model on the strength of its simple interpretation of random walkers as a reasonable way to rank the top college football teams (or at least as reasonable as other available methods, given the scarcity of games played relative to the number of teams—but we warn that this naive random walker ranking does a poor job ranking college basketball, where the margin of victory and established home-court advantage are significant [19]). This simple scheme has the advantage of having only one explicit, precisely defined parameter with a meaningful interpretation easily understood at the level of single-voter behavior. We have investigated the historical performance and mathematical properties of this ranking system elsewhere [3], [4]. At p close to $1/2$, the ranking is dominated by an RPI-like ranking in terms of a team's record, opponent's records, etc., with little regard for individual game outcomes. For p near 1, on the other hand, the ranking depends strongly on which teams won and lost against which other teams.

Our initial questions can now be rephrased playfully as follows: Can a bunch of monkeys rank football teams as well as the systems currently in use? Now that we have crossed over into the Year of the Monkey in the Chinese calender and the BCS has recently proposed changes to their non-BCS rules, it seems reasonable to ask whether the monkeys can clarify the effects of these planned changes.

Impact of Proposed Changes on Non-BCS Schools

The complete details of the new agreement have not yet been released, but indications are that the proposed rules would have given four at-large BCS bids to non-BCS schools over the past six years [13]. Based on the BCS Standings, the best guesses at those four teams are 1998 Tulane (11-0, BCS #10, poll average 10), 1999 Marshall (12-0, BCS #12, poll average 11), 2000 TCU (10-1, BCS #14, poll average 14.5), and 2003 Miami of Ohio (12-1, BCS #11, poll average 14.5). However, there are also indications that only non-BCS teams finishing in the BCS top 12 would automatically get bids [15], and each of the four schools above would have had to be given one of the at-large bids over at least one team ahead of them in the BCS Standings [8].

Given the perception that the polls unfairly favor BCS schools, it is worth noting the contrary evidence from six seasons of BCS Standings. In addition to the four schools listed above, other notable non-BCS campaigns were conducted this past season by Boise State (12-1, BCS #17, poll average 17) and TCU (11-1, BCS #18, poll average 19). Five of these six schools earned roughly the same ranking in the BCS standings and the polls. The only significant exception was 2003 Miami of Ohio, averaging 6th in the official BCS computer algorithms but only 14.5 in the polls.

While the new rules might indeed give BCS bowl bids to all non-BCS schools who finish in the top 12, it is worth inquiring how close non-BCS schools

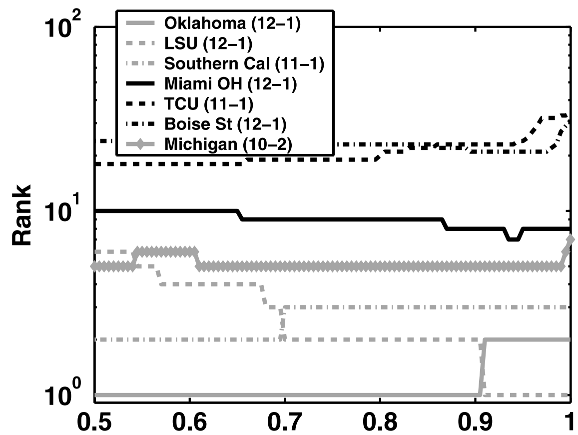

Figure 1. Random-walking monkey rankings of selected teams for 2003.

may have come to this or to a top 6 ranking that would have guaranteed them a bid during the past six years. In particular, 2003 was the first time in the BCS era that there were no undefeated teams remaining prior to the bowl games. Given that there were six one-loss teams and no undefeateds, what would have happened if one or more of the three non-BCS teams had instead gone undefeated? While it is impossible to guess how the polls would have behaved and we are unable to reproduce most of the official computer rankings, we can instead compute the resulting "random-walking monkey" rankings for different values of the bias parameter p. As a baseline, Figure 1 plots the end-of-season, pre-bowl-game rankings of each of the six one-loss teams, plus Michigan, from the true 2003 season (scaled logarithmically so that the top 2, top 6, and top 12 teams are clearly designated).

Now consider what would have transpired had Miami of Ohio, TCU, and Boise State all gone undefeated. Figure 2 shows the resulting rankings of the same teams as Figure 1 under these alternative outcomes. In the limit $p \to 1$, going undefeated trumps any of the one-loss teams, so each of these mythically undefeated schools ranks in the top 3 in this limit. For TCU and Boise State, however, their range of p in the top 6 is quite narrow. If the new rules require only a top 12 finish for a non-BCS team, then the situation looks much brighter for an undefeated TCU, which earned monkey rankings in the top 11 at all p values. However, according to the scenario plotted in Figure 2, an undefeated Boise State's claim on a BCS bid remains tenuous even under the proposed changes. Indeed, even had Boise State been the only undefeated team last season (not shown), the monkeys would have left them out of the top 10 and behind Miami of Ohio for $p \lesssim 0.86$.

At the other extreme, one-loss Miami of Ohio already has a legitimate claim to the top 12 according to both the monkeys *and* the real BCS Standings. Note, in particular, the exalted ranking

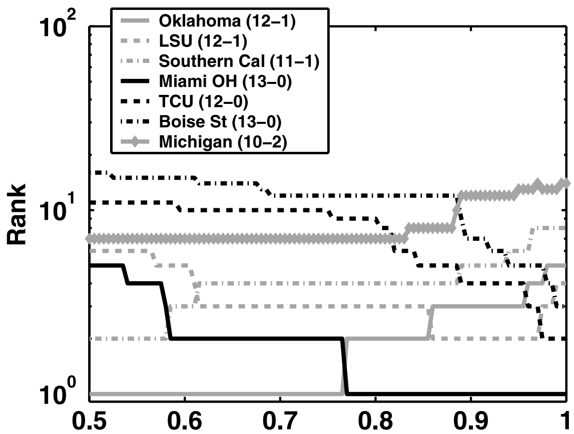

Figure 2. Random-walking monkey rankings of selected teams for an "alternate universe" 2003 in which the three non-BCS, one-loss teams instead went undefeated.

the monkeys would have given Miami of Ohio had they won their season opener against Iowa (their only loss in the actual 2003 season). According to the monkeys, they may have even had a reasonable argument to be placed in the championship game had they gone undefeated. It was bad enough not being able to fit three teams onto the field for the BCS National Championship game, but we might have been one Miami of Ohio victory over Iowa away from wanting to crowd four squads into the mix!

As an example of how the effects of games propagate into the rankings of other teams, we also include Michigan's ranking in both figures, even though their outcomes were not changed in the calculations that produced the two plots. Nevertheless, because Michigan is a next-nearest neighbor of Miami of Ohio in the network (both teams lost to Iowa in 2003), changing the outcome of the Iowa v. Miami of Ohio game unsurprisingly affects Michigan's ranking detrimentally.

To conclude this section, we stress that the above discussion is purely hypothetical, as the monkeys provide only a stand-in for our inability to compute true BCS Standings under alternative outcomes.

The Problem at the Top, and a Possible Solution

While we focused above on non-BCS schools and the recent changes that improve their chances of playing in a BCS bowl game, the larger BCS controversy for many fans is the recurring inability of the BCS to generate a championship game between conclusive "top 2" teams. Each of the past four seasons, the two polls agreed on the top two teams prior to the bowl games. In three of those seasons, however, the top two spots in the BCS Standings included only one of the teams selected by the polls. In 2000 and 2001, the #2 team in the polls ended up on the short end of the BCS stick, whereas in 2003 it was USC (the #1 team in both polls) on the outside looking in.

Although it is easy to blame this situation on the computer rankings, the true problem as we see it lies in the BCS formula of polls, computers, schedule strength, losses, and quality wins. Simply, the polls and computers already account for schedule strength and "quality wins", or else the three non-BCS one-loss teams (Miami of Ohio, TCU, and Boise State) would have placed in the top 6 in the 2003 BCS Standings. Adding these factors *again* after the polls and computer rankings are determined disastrously double-counts these effects, adversely degrading confidence in the BCS selections for the National Championship and the other BCS bowls.

One of the presumed motivations for including separate factors for schedule strength and quality wins was to reduce the assumed bias of the polls towards traditional football powers. However, as discussed above, the top non-BCS teams over the past six years were ranked similarly in the polls and computers. Therefore, one might rightly worry that the quality wins and schedule strength factors are making it harder for non-BCS schools to do well in the standings, as their schedules are typically ranked significantly lower and they have few opportunities for so-called "quality wins".

USC was on the losing end of this double-counting in 2003, having finished the regular season #1 in both polls and averaged #2.67 on the computers. LSU was #2 in both polls and averaged #1.93 on the computers, and Oklahoma was #3 in both polls and averaged #1.17 on the computers. One of the official computer systems even ranked non-BCS Miami of Ohio ahead of USC. However, although the computers ranked Oklahoma ahead of the other teams, it was Oklahoma's 11th place schedule strength and -0.5 "quality win" bonus for beating Texas that combined to give it an additional 1.55 BCS-points edge compared to USC's 37th place schedule (standings available from [18]). With six one-loss teams in Division I-A, the ranking algorithms predominantly favored Oklahoma *because* of its relatively difficult schedule and its victory over Texas. Without those effects being included *again* in separate quality wins and schedule strength factors, a straight-up averaging of the polls and the computers would rank USC first (1+2.67=3.67), LSU second (2+1.93=3.93), and Oklahoma third (3+1.17=4.17).

A reasonable knee-jerk reaction to this proposal would be to reassert that schedule strength, number of losses, and so-called quality wins should matter. Our point is that they are *already* incorporated in such a simple averaging scheme, as the polls and the computers (necessarily) consider such factors to produce reasonable rankings. To explicitly add further BCS points for each of these considerations gives them more weight than the collective wisdom of the polls and computer rankings believe they should have.

Whatever solution is ultimately adopted, we strongly advocate that modifications to the BCS remove such double-counting and, ideally, provide a system that is more open to the community. That the double-counting problem is not widely appreciated further supports our opinion that the BCS system needs to be more transparent. The recently announced addition of a fifth BCS bowl does not address this problem.[2]

College football fans should not have to accept computer rankings without a minimal explanation of their determining ingredients, not only so that they have more confidence in these algorithms, but also to open debate about what factors should be included and how much they should be weighted. For example, there is certainly a need to discuss how much losing a game late in the season or in a conference championship game (as Oklahoma did in 2003) should matter compared to an earlier loss.

Even before the end-of-season controversy in 2003, a survey conducted by New Media Strategies indicated that 75 percent of college football fans thought that the BCS system should be scrapped entirely [9]. That number presumably increased after the new round of controversy. Changes that lead to greater transparency and a simplified weighted averaging of the polls and computers are the only way anything resembling the current BCS system can maintain popular support.

Epilogue

New information appearing after the original writing of this review claims that the double-counting factors in the BCS formula may be scrapped in favor of an average of polls and computer rankings [2]. We submitted advance copies of this article to BCS decision makers, but we have no knowledge that any changes resulted directly from our input. It was announced on July 15th that the new BCS Standings wil be determined by equally weighting the AP poll, the *USA Today*/ESPN Coaches poll, and an average over the computer systems (that is, 2/3 polls, 1/3 computers). One might worry that this weighting effectively relegates the computers to tie breaking, a posteriori yielding National Championship pairings in agreement with the polls over each of the past six seasons and placing any possibility of a midmajor school getting a BCS bid almost wholly in the hands of poll voters. Nevertheless, such a change clearly simplifies the BCS Standings, which we view as positive.

---

[2] *However, it appears that even more recent changes may simplify the BCS formula by removing the double counting; see the Epilogue.*

References

[1] R. Billingsley, College football research center, `http://cfrc.com/` (as downloaded in January 2004).

[2] T. Barnhart, More changes ahead for BCS, *The Atlanta Journal-Constitution* (May 12, 2004).

[3] T. Callaghan, M. A. Porter, and P. J. Mucha, Random walker ranking for NCAA Division I-A football, submitted (2003). E-print: `arxiv.org/physics/0310148`.

[4] T. Callaghan, M. A. Porter, and P. J. Mucha, How well can monkeys rank football teams? `http://www.math.gatech.edu/~mucha/BCS` (as downloaded in January 2004).

[5] W. N. Colley, ColleyMatrix: Colley's bias free matrix rankings, `http://www.colleyrankings.com/` (as downloaded in January 2004).

[6] G. R. Connor and C. P. Grant, An extension of Zermelo's model for ranking by paired comparisons, *European J. Appl. Math.* **11** (2000), 225–247.

[7] M. Fish, Stuff happens, `SI.com` (December 9, 2003).

[8] P. Fiutak, Cavalcade of whimsy: Fifth BCS game is silly, `CollegeFootballNews.com` (March 4, 2004).

[9] T. Hyland, Survey: College football fans say BCS has to go, *Baltimore Business J.* (December 3, 2003).

[10] J. P. Keener, The Perron-Frobenius theorem and the ranking of football teams, *SIAM Rev.* **35** (1993), 80–93.

[11] B. Kirlin, How to fake having your own math formula rating system to rank college football teams, `http://www.cae.wisc.edu/~dwilson/rsfc/history/kirlin/fake.html` (as downloaded in 2003).

[12] T. Layden, Pleading the fifth: BCS powers don't go far enough in latest reform, `SI.com` (March 5, 2004).

[13] M. Long, BCS agrees to add fifth bowl game, Associated Press (March 1, 2004).

[14] M. Lupica, If this all adds up, subtract 'C' from BCS to name bowl, *New York Daily News* (December 8, 2003).

[15] S. Mandel, Presidental seal: Different decision-makers send BCS in unlikely direction, `SI.com` (March 4, 2004).

[16] J. Martinich, College football rankings: Do the computers know best?, *Interfaces* **32** (2002), 85–94.

[17] K. Massey, Massey ratings, `http://www.masseyratings.com/` (as downloaded in January 2004).

[18] The National Football Foundation, The bowl championship series overview, `http://www.footballfoundation.com/bcs.php` (as downloaded in January 2004).

[19] J. Sokol, personal communication.

[20] W. Suggs, Presidents see progress in opening up big-money bowls to more colleges, *Chronicle of Higher Ed.* **50** (November 28, 2003), A38.

[21] Whitaker Software Applications, Football rankulator, `http://www.footballrankulator.com/` (as downloaded in 2003).

[22] D. L. Wilson, American college football—rankings, `http://www.cae.wisc.edu/~dwilson/rsfc/rate/` (as downloaded in January 2004).

[23] P. R. Wolfe, 2003 college football, `http://www.bol.ucla.edu/~prwolfe/cfootball/ratings.htm` (as downloaded in January 2004).