Evaluating individual performance in team sports: A network analysis of Batsmen and Bowlers in Cricket

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Abstract

Quantifying individual performance in team activity is critical in team selection in international sports. We explore the application of Social Network Analysis (SNA) to rate individuals in a team activity. We choose the game of Cricket as an example. The number runs scored by batsmen and wickets taken by bowlers serves as a natural way of quantifying the performance of a cricketer. Traditionally the batsmen and bowlers are rated on their batting or bowling average respectively. However in a game like cricket it is always important the manner in which one scores the runs or takes a wicket. Scoring runs against a strong bowling line-up or delivering a brilliant performance against a team with strong batting line-up deserves more credit. A player’s average is not able to capture this aspect of the game. In this paper we present a refined method to quantify the ‘quality’ of runs scored by a batsman or wickets taken by a bowler. We apply tools of Social Network Analysis (SNA) to judge a cricketer’s performance. We generate directed and weighted network of batsmen-bowlers using the player-vs-player information available for Test cricket and ODI cricket. Additionally we generate network of batsmen and bowlers based on the dismissal record of batsmen in the history of cricket - Test (1877 – 2011) and ODI (1971 – 2011). Our results show that SNA approach could provide a refined rating of batsmen and bowlers in history of cricket. Our approach could potentially be applied in domestic cricket to judge a player’s performance which in turn pave the way for a balanced team selection for International matches.

Keywords: Social network analysis, in-strength, sports, cricket.
1. Introduction

Quantifying the individual performance or ‘quality’ of a player in any sport is a matter of great importance for the selection of team members in international competitions and is a topic of recent interest. A lot of negotiations are involved in the process of team-selection. We take the case of individual performance of batsmen and bowlers in International cricket matches. Cricket is a game played in most of the Commonwealth countries. The International Cricket Council (ICC) is the government body which controls the cricketing events around the globe. Although ICC includes 120 member countries, only ten countries with ‘Test’ status - Australia, England, India, South Africa, New Zealand, West Indies, Bangladesh, Zimbabwe, Pakistan and Sri Lanka play the game extensively. There are three versions of the game - ‘Test’, One Day International (ODI) and Twenty20 (T20) formats. Test cricket is the longest format of the game dating back to 1877. Usually it lasts for five days involving 30 – 35 hours. Shorter formats, lasting almost 8 hours like ODI started in 1971 and during late 2000 ICC introduced the shortest format called T20 cricket which lasts approximately 3 hours.

Batsmen and Bowlers in cricket are traditionally ranked according to their batting and bowling average respectively. Judged by the batting average, Sir Donald Bradman (with an average of 99.94) is regarded as the greatest batsman of all times. The next best batting average of 60.9 is held by Graeme Pollock. Even though most of the records held by Bradman has been eclipsed by modern day batsmen like Sachin Tendulkar, Brian Lara, Graham Gooch, Mohammad Yusuf, Bradman’s legacy still survives and generates debate among fans about his greatness relative to recent players like Sir Vivian Richards, Brian Lara or Sachin Tendulkar. The question thus naturally arises is whether batting average of batsmen (or
bowling average of bowlers) are the best measure for judging the worth of a batsman. It was shown that rankings based on average suffer from two defects - i) Consistency of scores across innings and ii) Value of runs scored by the player [1]. However one should also consider the quality of bowling as well. For example according to Bradman himself, the greatest innings he ever witnessed was that of McCabe’s innings of 187 at Sydney in 1932. The reason being it came against Douglas Jardine’s body-line attack, widely regarded as one of the fiercest bowling attacks. Similarly runs scored against West Indian bowlers like Michael Holding, Joel Garner, Malcom Marshall and Andy Roberts deserve more credit than runs scored against low bowling attack of Bangaldesh or Zimbabwe. On similar arguments the wicket of top-order batsman is valued more than the wicket of a lower-order batsman. Hence if a bowler dismiss Bradman, Lara, Richards or Tendulkar, he gets more credit than if he dismiss any lower-order batsman. Under the usual ranking scheme based on bowling average, George Lohmann of England has the lowest (best) bowling average (10.75) in Test cricket. However bowlers like George Lohmann played under pitch conditions favoring fast bowlers. Hence batting (or bowling) average does not serve as an efficient gauge for a batsman’s (or bowler’s) ability [2]. Against, this background, we propose a network based approach to quantify the ‘quality’ of a batsman or bowler.

In recent years there has been an increase in study of quantitative analysis of individual performance involving team sports. Time series analysis have been applied to football [3, 4], baseball [5, 6], basketball [7, 8, 9] and soccer [10, 11]. Studies have focussed on non-linear modeling techniques like neural networks to rate an individual’s performance. For example, neural networks techniques were used to predict the performance of individual cricketer’s based on their past performance [12]. Again, a model-free approach was developed to extract the outcome of a soccer match [13]. In recent years, the study of complex networks have attracted a lot of research interests [14]. The tools of complex network analysis have previously been applied to quantify individual brilliance in sports and also to rank the
individuals based on their performance. For example, a network approach was developed to quantify the performance of individual players in soccer [15]. Network analysis tools have been applied to football [16] and Brazilian soccer players [17]. Successful and un-successful performance in water polo have been quantified using a network-based approach [18]. Head-to-head matchups between Major League Baseball pitchers and batters was studied as a bipartite network [19]. More recently a network-based approach was developed to rank US college football teams [20], tennis players [21] and cricket teams and captains [22].

The complex features of numerous social systems are embedded in the inherent connectivity among system components [14, 18]. Social network analysis (SNA) provides insight about the pattern of interaction among players and how it affects the success of a team [23]. This article points out that how topological relations between players help better understanding of individuals who play for their teams and thus elucidate the individual importance and impact of a player. In this paper we apply the tools of network analysis to batsmen and bowlers in cricket and quantify the ‘quality’ of an individual player. The advantage of network based approach is that it provides a different perspective for judging the excellence of a player. The rest of the paper is presented as follows : In Section 2 we propose the methods of link formation among the batsmen and bowlers. In section 3 we discuss the results and we conclude in Section 4.

2. Methodology

We obtained data from the cricinfo website [24]. The website holds the information of proceedings of all Test matches played since 1877 and all ODI matches from 1971 onwards. These include the runs scored by batsmen, wickets taken by bowlers, outcome of a game and also the information of the mode of dismissal of a batsman. We collect the data of player-vs-player for Test cricket (2001 – 2011), ODI cricket (1999 – 2011) from the cricinfo website. The data of player-vs-player contains the information of runs scored by a batsman
against every bowler he faced and also how many times he was dismissed by the bowlers he faced. No information of player-vs-player is available for games played earlier than 2001. We also collect the batting and bowling averages of players from the player’s profile available in the cricinfo website. Batting average of a batsman is defined as the total number of runs scored by the batsman divided by the number of times he was dismissed. Thus higher batting average reflects higher ‘quality’ of a batsman. Similarly, bowling average is defined as the number of runs given by the bowler divided by the number of wickets claimed by him. Thus lower bowling average indicates higher ability of the bowler. These informations are used to generate the network of interaction among bowlers and batsmen in cricket matches.

2.1. Weighted and Directed Network

Cricket is a bat-and-ball game played between two teams of 11 players each. The team batting first tries to score as many runs as possible, while the other team bowls and fields, trying to dismiss the batsmen. At the end of an innings, the teams switch between batting and fielding. This can be represented as a directed network of interaction of batsmen ($B_a$) and bowlers ($B_o$). Every node in $B_o$ has a directed link to all nodes in $B_a$, provided the batsman and bowler face each other. The performance of a batsman is judged by the ‘quality’ of runs scored and not the number of runs scored. Hence runs scored against a bowler with lower bowling average carries more credit than runs scored against a bowler of less importance. We introduce a performance index of a batsman ($PIB$) against a bowler given by the following equation

$$PIB = \frac{A_{Ba}}{C_{Bo}}$$  \hspace{1cm} (1)

where, $A_{Ba}$ is the batting average of the batsman against the bowler he faced and $C_{Bo}$ refers to the career bowling average of the bowler. Mathematically, batting average of the batsman ($A_{Ba}$) is given by the ratio $\frac{R}{d}$ where $R$ is the number of runs scored against a bowler and $d$
is the number of times he was dismissed by the bowler. Hence if the career bowling average of a bowler is low (indicating a good bowler), $PIB$ increases indicating that the batsman scored runs against quality opposition. We generate weighted and directed network of bowlers to batsmen where weight of the link is given by $PIB$. The network generated is thus based on the directed interaction of $B_o$ and $B_a$. For the weighted network the in-strength $s_i^{in}$ is defined as

$$s_i^{in} = \sum_{j \neq i} W_{ji}$$  \hspace{1cm} (2)$$

where $W_{ji}$ is given by the weight of the directed link.

So far we have concentrated on the performance index of batsmen since 2001. Although the data for player-vs-player is not available for dates earlier than 2001, one could quantify the overall performance of a bowler based on the dismissal record of batsmen. For example, the wicket of a top-order batsman always deserve more credit than the wicket of a tail-ender. Thus the 'quality' of dismissal serves as a measure for the greatness of a bowler. We define the quality index of bowler ($QIB$) as

$$QIB = D \frac{C_{Ba}}{C_{Bo}}$$  \hspace{1cm} (3)$$

where $D$ is defined as the number of times a batsman was dismissed by a particular bowler, $C_{Ba}$ refers to the career batting average of a batsman and $C_{Bo}$ indicates the career bowling average of a bowler. Thus greater the value of $QIB$, better is the rank of a bowler. As before we construct weighted and directed networks, this time the directed link pointing towards the bowlers. We evaluate the in-strength of the bowlers, which serves as a quantification of the ‘quality’ of a bowler.
Figure 1: (Color online) (A) Subgraph of the substrate network of batsmen and bowlers in ODI (1971 – 2011). The thickness of the directed link is proportional to the $QIB$. (B) The resultant gradient network of bowlers is constructed if the bowlers dismiss the same batsman (here it is *Wasim Akram*). The direction and weights of the links are applied according to the gradient scheme of link formation.
2.2. Gradient Network

The manner in which the game is played doesn’t allow us to compare the relative dominance of one batsman over another batsman or one bowler over another bowler. Unlike in tennis, where each player has to compete directly with the opponent, in cricket a batsman is pitted against a bowler. Hence it is very difficult to judge the relative superiority of a batsman (bowler) over another batsman (bowler). In this section we introduce gradient links between batsmen who face the same bowler. Recent studies have shown that transport efficiencies are often driven by local gradients of a scalar [25]. It has been seen that a gradient network based on a random graph topology tends to get easily congested, in the large network limit. If the substrate network is scale-free [26], then the corresponding gradient network is the least prone to congestion [27]. Traditionally a gradient network is constructed as follows. Consider a substrate network $S$. Each node $i$ in the network is assigned with a random number $h_i$ which describes the ‘potential’ of the node. Gradient network is constructed by directed links that point from each node to the nearest neighbor with highest potential [27]. Here we take a slightly different route to construct the weighted-gradient network.

We evaluate the in-strength $s_{i}^{\text{in}}$ of the nodes of the substrate network (See Figure 1(A)). The in-strength acts a ‘potential’ for each node (batsman or bowler). We construct gradient links between two batsmen along the steepest ascent, where the weight of the directed link is the difference of the in-strength of two nodes. Thus weighted and directed links are formed between two bowlers if they dismiss the same batsman. Additionally we introduce a constraint, in which two bowlers are linked only if they are contemporary (See Figure 1(B)). Thus the weight $\omega_{ij}$ of a link is given as

$$\omega_{ij} = |s^{\text{in}}_i - s^{\text{in}}_j|$$

$^{1}$R and d are evaluated for Test matches played between 2001 and 2011 and ODI (1999 – 2011)
where $s_{ij}^{in}$ are the in-strength of two nodes $i$ and $j$. The gradient network thus highlights the relative importance of a player over other. Next we apply the PageRank algorithm on the resultant gradient network and evaluate the importance of each player.

2.2.1. PageRank algorithm

We quantify the importance or ‘popularity’ of a player with the use of a complex network approach and evaluating the PageRank score. Mathematically, the process is described by the system of coupled equations

$$p_i = (1 - q) \sum_j p_j \frac{\omega_{ij}}{s_j^{out}} + \frac{q}{N} + \frac{1-q}{N} \sum_j \delta \left( s_j^{out} \right),$$

(5)

where $\omega_{ij}$ is the weight of a link and $s_j^{out} = \Sigma_i \omega_{ij}$ is the out-strength of a link. $p_i$ is the PageRank score assigned to team $i$ and represents the fraction of the overall “influence” sitting in the steady state of the diffusion process on vertex $i$ [21]. $q \in [0, 1]$ is a control parameter that awards a ‘free’ popularity to each player and $N$ is the total number of players in the network. The term $(1 - q) \sum_j p_j \frac{\omega_{ij}}{s_j^{out}}$ represents the portion of the score received by node $i$ in the diffusion process obeying the hypothesis that nodes redistribute their entire credit to neighboring nodes. The term $\frac{q}{N}$ stands for a uniform redistribution of credit among all nodes. The term $\frac{1-q}{N} \sum_j p_j \delta \left( s_j^{out} \right)$ serves as a correction in the case of the existence of nodes with null out-degree, which otherwise would behave as sinks in the diffusion process. It is to be noted that the PageRank score of a player depends on the scores of all other players and needs to be evaluated at the same time. To implement the PageRank algorithm in the directed and weighted network, we start with a uniform probability density equal to $\frac{1}{N}$ at each node of the network. Next we iterate through Eq. (5) and obtain a steady-state set of PageRank scores for each node of the network. Finally, the values of the PageRank score are sorted to determine the rank of each player. According to tradition, we use a uniform value of $q = 0.15$. This choice of $q$ ensures a higher value of PageRank scores [21].
3. Results

In this section, we explore the in-strength distribution of the weighted and directed networks. The in-strength of a node is an indication of the performance of an individual against the opponent team member. Thus higher the in-strength, better the performance. In Fig 2 we plot the cumulative in-strength distribution of batsmen and bowlers in Test cricket and ODI cricket. As we can see, the in-strength distributions do not display power-law or normal distribution.

As mentioned above the in-strength of a batsman reflects the performance of a batsman in terms of quality of runs scored. In Table 1 we list the top 50 batsmen in Test cricket between 2001 and 2011. The batsmen are ranked according to their in-strength. We observe that K. C. Sangakkara of Sri Lanka occupies the top spot followed by India’s S. R. Tendulkar with Australia’s R. T. Ponting and South Africa’s J. H. Kallis occupying the third and fourth spot respectively. R. Dravid of India occupies the fifth position. We compare the in-strength rank with the PageRank score and batting average of batsmen for runs scored between 2001 and 2011. Additionally we list the best ever cricket rating received by a batsman between...
2001 and 2011. Judged by the batting average and the ICC points we observe that B. C. Lara of West Indies emerge as the most successful batsman in Test cricket between 2001 and 2011. Similarly Australia’s R. T. Ponting averages more than S. R. Tendulkar and K. C. Sangakkara. However both K. C. Sangakkara and S. R. Tendulkar accumulated runs against better bowling attack. In Table 2 we list the top 50 batsmen in ODI cricket (1999 – 2011). This time too K. C. Sangakkara emerge as the most successful batsman followed by Australia’s R. T. Ponting and India’s S. R. Tendulkar. Even though S. R. Tendulkar averages more than his predecessors and also received the highest ICC points, both K. C. Sangakkara and R. T. Ponting scored runs against better bowling attack. In Figure 3 we compare the correlation of ranks obtained from in-strength and batting average. We observe that both the ranking schemes show strong correlation. Please note that this ranking is sensitive to change in information of player-vs-player once the information prior to the year 2000 is available in the cricinfo website.

We provide the historical ranking of bowlers for Test cricket in Table 3. We observe that the bowlers ranked by the average are different from that obtained from SNA. Finally we rank the performance of all bowlers in Test cricket (1877–2011), and identify bowlers with highest influence. We observe that according to in-strength values Sri Lanka’s M. Muralitharan emerge as the most successful bowler in the history of Test cricket (1877 – 2011) followed by S. K. Warne (AUS), G. D. McGrath (AUS), A. Kumble (IND) and C. A. Walsh (WI) (See Table 3). As before we generate gradient network of bowlers and apply the PageRank algorithm. It is interesting to note that the top five bowlers according to PageRank score are M. Muralitharan (SL), S. K. Warne (AUS), G. D. McGrath (AUS), F. S. Trueman (ENG) and C. A. Walsh (WI) (See Table 3). Thus according to quality of ‘dismissal’ and relative ‘popularity’ of bowlers M. Muralitharan emerge as the most successful bowler in Test cricket. Interestingly, M. Muralitharan is the highest wicket-taker in Test cricket. His success could be a posteriori justified by his long and successful career spanning 18 years.
(between 1992 and 2010). During his entire career M. Muralitharan dismissed 800 batsmen (highest in Test cricket) which included the likes of S. R. Tendulkar (dismissed 14 times), R. Dravid (dismissed 12 times) and B. C. Lara (dismissed 9 times). In addition to this he holds the record of maximum number of five wickets in an innings (67 times) and ten wickets in a match (22 times). We also observe that S. K. Warne, the second best bowler in Test cricket has second highest number of dismissals (708) to his credit. Both these bowlers had extremely long and successful careers spanning almost two decades. Australia’s G. D. McGrath, who has been considered one of the best fast bowlers in cricket holds a better average than that of his immediate predecessors. However his in-strength rank and PageRank score indicates that his quality of dismissal were not better than Muralitharan or Warne. This leads to the possible question - are bowling averages the best indicator of a bowler’s ability?. In our all time top 50 list we observe that England’s S. F. Barnes has the best bowling average of 16.43 and highest ICC points of 932 among all the bowlers (as listed in Table 3). However like George Lohmann, S. F. Barnes too enjoyed favorable pitch conditions. The batsmen playing in such pitches usually averaged lower than the recent batsmen. Hence for players like S. F. Barnes, the QIB is low which in turn affects his in-strength. However, his PageRank score his higher than most of the modern age bowlers indicating his relative ‘popularity’ or supremacy over other bowlers. A similar situation is seen with Pakistan’s Imran Khan. Although his in-strength is lower than that of Wasim Akram or D. K. Lillee, his PageRank score is higher than most of his predecessors. Rankings based on SNA show little agreement with traditional methods of performance evaluation. This is supported by the low positive correlation between different ranking schemes (See Figure 3(A, B)).

In ODI history (1971 – 2011) too, Sri Lanka’s M. Muralitharan leads the list of top 50 bowlers, followed by Pakistan’s Wasim Akram, Australia’s G. D. McGrath, Pakistan’s Waqar Younis and South Africa’s S. M. Pollock. PageRank scores reveal that M. Muralitharan is
the most successful bowler followed by Wasim Akram (PAK), Waqar Younis (PAK), G. D. McGrath (AUS) and B. Lee (AUS). Although G. D. McGrath has a slightly better average than M. Muralitharan, he falls short of the latter in terms of in-strength, PageRank score and ICC points. Again, judged by the number of dismissals, M. Muralitharan heads the list with 534 wickets, with Wasim Akram and Waqar Younis occupying the second and third position respectively. There are few surprises in the list. India’s A. B. Agarkar is placed above in comparison to N. Kapil Dev (IND), C. E. L. Ambrose (WI) or C. A. Walsh (WI) whom cricket experts consider as better bowlers. However, what goes in favor of A. B. Agarkar is the ‘quality’ of wickets he took. Thus even though he went for runs and didn’t have a long career, he was able to dismiss most of the batsmen with good average.

We observe the ranks obtained from in-strength (or PageRank) and bowling average are anti-correlated (See Figure 4(B,C)). This is not surprising in the sense that bowling average is not a proper way of judging a player’s performance. Also in the ODIs, there has been a practice of bringing in part-time bowlers who have low-averages. This is paradoxical in the sense that it indicates part-time bowlers are better than the regular bowlers. We find that our scheme provides sensible results that are in agreement with the points provided by ICC2. We also observe strong correlation between ranks obtained by network based tools and that provided by ICC3 (Figure 5). This demonstrates that our network based approach captures the consensus opinions.

4. Conclusion

To summarize, we quantified the performance of batsmen and bowlers in the history of cricket by studying the network structure of cricket players. Under the usual qualification of

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2The rankings provided by ICC take in account several factors like runs scored, quality of pitch and opposition, match result etc. However, due to its opaqueness, ICC’s methodology is incomprehensible. Our approach is both novel and transparent.

3Since the information of ICC points is not consistent we choose the information of top 200 bowlers.
Table 1: Ranking of top 50 batsmen in Test cricket (2001 – 2011). We compare the rank of the batsmen according to their In-strength and compare them with the corresponding PageRank score, Batting average and best ever points according to ICC ratings.

| Rank | Batsman               | Country     | In-strength | PageRank Score | Batting Average | ICC Points |
|------|-----------------------|-------------|-------------|----------------|-----------------|------------|
| 1    | K. C. Sangakkara      | Sri Lanka  | 131.520     | 0.189813       | 59.43           | 938        |
| 2    | S. R. Tendulkar       | India      | 115.460     | 0.065442       | 55.13           | 898        |
| 3    | R. T. Ponting         | Australia  | 113.582     | 0.049806       | 59.93           | 942        |
| 4    | J. H. Kallis          | South Africa | 103.545   | 0.030825       | 66.66           | 935        |
| 5    | R. Dravid             | India      | 100.344     | 0.023313       | 54.31           | 892        |
| 6    | V. Sehwag             | India      | 100.076     | 0.022345       | 55.41           | 883        |
| 7    | D. P. M. D. Jayawardene | Sri Lanka | 99.131     | 0.022345       | 55.41           | 883        |
| 8    | V. V. S. Laxman       | Sri Lanka  | 97.555      | 0.020722       | 66.66           | 935        |
| 9    | S. Chanderpaul        | Sri Lanka  | 96.319      | 0.019905       | 56.40           | 901        |
| 10   | G. C. Smith           | South Africa | 88.943   | 0.014527       | 50.28           | 843        |
| 11   | M. L. Hayden          | Australia  | 85.628      | 0.012232       | 57.15           | 880        |
| 12   | Younis Khan           | Pakistan   | 83.255      | 0.011589       | 57.15           | 880        |
| 13   | R. C. Lara            | West Indies | 82.112    | 0.011589       | 57.15           | 880        |
| 14   | A. N. Cook            | England    | 80.407      | 0.008708       | 48.69           | 836        |
| 15   | A. J. Strauss         | England    | 78.447      | 0.008470       | 41.60           | 769        |
| 16   | K. P. Pietersen       | England    | 77.312      | 0.007912       | 50.79           | 909        |
| 17   | C. H. Gayle           | West Indies | 74.070    | 0.007991       | 43.27           | 755        |
| 18   | A. B. de Villiers     | South Africa | 73.922   | 0.007441       | 43.27           | 755        |
| 19   | M. E. K. Hussey       | Australia  | 70.899      | 0.006557       | 51.29           | 921        |
| 20   | M. P. Vaughan         | England    | 65.216      | 0.005795       | 44.28           | 876        |
| 21   | T. T. Samarasekera    | Sri Lanka  | 64.221      | 0.006355       | 60.08           | 750        |
| 22   | J. L. Langer          | Australia  | 62.221      | 0.005165       | 50.69           | 780        |
| 23   | R. R. Sarwan          | West Indies | 58.056    | 0.005216       | 41.94           | 767        |
| 24   | B. R. McCullum        | New Zealand | 57.958    | 0.004427       | 36.90           | 673        |
| 25   | D. L. Vettori         | New Zealand | 57.919    | 0.004179       | 35.70           | 672        |
| 26   | M. J. Clarke          | Australia  | 57.830      | 0.004501       | 50.43           | 855        |
| 27   | H. H. Gibbs           | South Africa | 57.566   | 0.004485       | 46.67           | 825        |
| 28   | I. R. Bell            | England    | 57.356      | 0.004460       | 47.80           | 822        |
| 29   | M. E. Trescothic      | England    | 55.499      | 0.003753       | 45.83           | 818        |
| 30   | T. M. Dilhara         | Sri Lanka  | 54.190      | 0.005119       | 44.37           | 700        |
| 31   | A. C. Gilchrist       | Australia  | 53.751      | 0.003999       | 48.16           | 874        |
| 32   | D. R. Martyn          | Australia  | 53.141      | 0.003723       | 48.32           | 848        |
| 33   | H. M. Amla            | South Africa | 52.579   | 0.003863       | 48.52           | 842        |
| 34   | A. Flintoff           | England    | 48.845      | 0.003620       | 34.06           | 645        |
| 35   | Imran Khan al Haq     | Pakistan   | 46.838      | 0.003417       | 57.37           | 970        |
| 36   | S. T. Jayawardena     | Sri Lanka  | 46.401      | 0.003044       | 42.66           | 770        |
| 37   | S. M. Katich          | Australia  | 45.676      | 0.003037       | 46.01           | 807        |
| 38   | S. C. Ganguly         | India      | 45.418      | 0.002945       | 42.26           | 713        |
| 39   | M. V. Boucher         | South Africa | 44.699   | 0.004131       | 31.78           | 566        |
| 40   | L. R. P. L. Taylor    | New Zealand | 44.060    | 0.002538       | 45.72           | 775        |
| 41   | G. Gambhir            | India      | 43.806      | 0.002713       | 47.51           | 886        |
| 42   | P. D. Collingwood     | England    | 43.739      | 0.002763       | 40.57           | 730        |
| 43   | S. P. Fleming         | New Zealand | 43.874    | 0.002823       | 44.15           | 725        |
| 44   | M. S. Dhoni           | India      | 43.344      | 0.002406       | 37.84           | 662        |
| 45   | M. S. Atapattu        | Sri Lanka  | 40.912      | 0.002540       | 44.72           | 670        |
| 46   | A. G. Prince          | South Africa | 40.704    | 0.002530       | 43.12           | 756        |
| 47   | Habibul Baqar         | Bangladesh | 40.702      | 0.002456       | 31.03           | 656        |
| 48   | Mohammad Ashraful     | Bangladesh | 38.937      | 0.002442       | 22.62           | 491        |
| 49   | M. J. Prior           | England    | 38.594      | 0.001972       | 46.75           | 679        |
| 50   | Imran Farhat          | Pakistan   | 37.910      | 0.002399       | 33.03           | 575        |
Table 2: Ranking of top 50 batsmen in ODI cricket (1999 – 2011). We compare the rank of the batsmen according to their In-strength and compare them with the corresponding PageRank score, Batting average and best ever points according to ICC ratings.

| Rank | Batsman                | Country      | In-strength | PageRank Score | Batting Average | ICC Points |
|------|------------------------|--------------|-------------|----------------|----------------|------------|
| 1    | K. C. Sangakkara       | Sri Lanka    | 128.075     | 0.165704       | 42.59          | 863        |
| 2    | R. T. Ponting         | Australia    | 127.058     | 0.095677       | 46.94          | 829        |
| 3    | S. R. Tendulkar        | India        | 120.251     | 0.052469       | 50.90          | 898        |
| 4    | D. M. J. Jayawardene   | Sri Lanka    | 115.475     | 0.040357       | 38.33          | 738        |
| 5    | Yuvraj Singh          | India        | 109.620     | 0.027228       | 40.48          | 787        |
| 6    | V. Sehwag             | India        | 104.183     | 0.022008       | 40.48          | 787        |
| 7    | J. H. Kallis          | South Africa | 97.150      | 0.014652       | 49.89          | 817        |
| 8    | M. S. Dhoni           | India        | 96.639      | 0.014579       | 56.44          | 836        |
| 9    | Younis Khan           | Pakistan     | 90.378      | 0.013467       | 37.19          | 659        |
| 10   | S. T. Jayaseeni       | Sri Lanka    | 89.352      | 0.012719       | 36.13          | 838        |
| 11   | G. C. Smith           | South Africa | 88.873      | 0.011473       | 40.25          | 784        |
| 12   | M. J. Clarke          | Australia    | 86.790      | 0.010249       | 51.50          | 750        |
| 13   | R. Dravid             | India        | 85.407      | 0.009736       | 48.95          | 749        |
| 14   | A. C. Gilchrist       | Australia    | 79.554      | 0.008268       | 49.89          | 867        |
| 15   | C. H. Gayle           | West Indies  | 78.427      | 0.008227       | 48.10          | 776        |
| 16   | R. Dravid             | India        | 77.276      | 0.006517       | 53.15          | 857        |
| 17   | M. L. Hayden          | Australia    | 76.883      | 0.006100       | 46.95          | 850        |
| 18   | T. M. Dilshan         | Sri Lanka    | 71.624      | 0.005514       | 31.98          | 664        |
| 19   | M. J. Clarke          | Australia    | 71.192      | 0.004333       | 31.98          | 664        |
| 20   | M. E. K. Hussey       | Australia    | 71.192      | 0.004333       | 31.98          | 664        |
| 21   | S. M. Trescothick     | England      | 64.758      | 0.004741       | 39.50          | 697        |
| 22   | S. S. Ganguly         | India        | 64.623      | 0.004680       | 39.50          | 697        |
| 23   | K. P. Pietersen       | England      | 64.623      | 0.004680       | 39.50          | 697        |
| 24   | A. B. de Villiers     | South Africa | 64.623      | 0.004680       | 39.50          | 697        |
| 25   | S. M. Trescothick     | England      | 64.623      | 0.004680       | 39.50          | 697        |
| 26   | K. P. Pietersen       | England      | 64.623      | 0.004680       | 39.50          | 697        |
| 27   | A. B. de Villiers     | South Africa | 64.623      | 0.004680       | 39.50          | 697        |
| 28   | A. B. de Villiers     | South Africa | 64.623      | 0.004680       | 39.50          | 697        |
| 29   | W. U. Tharanga        | Sri Lanka    | 60.773      | 0.003835       | 37.38          | 663        |
| 30   | A. J. Strauss         | England      | 60.650      | 0.003818       | 37.29          | 664        |
| 31   | M. S. Atapattu        | Sri Lanka    | 60.328      | 0.003837       | 47.77          | 738        |
| 32   | S. F. Fleming         | New Zealand  | 54.770      | 0.003231       | 36.20          | 697        |
| 33   | I. A. S. Colomin      | New Zealand  | 54.770      | 0.003231       | 36.20          | 697        |
| 34   | A. S. Colomin         | New Zealand  | 54.770      | 0.003231       | 36.20          | 697        |
| 35   | A. S. Colomin         | New Zealand  | 54.770      | 0.003231       | 36.20          | 697        |
| 36   | Yousuf Youhana        | Pakistan     | 53.965      | 0.003072       | 40.68          | 801        |
| 37   | M. E. Trescothick     | Pakistan     | 53.965      | 0.003072       | 40.68          | 801        |
| 38   | M. E. Trescothick     | Pakistan     | 53.965      | 0.003072       | 40.68          | 801        |
| 39   | M. E. Trescothick     | Pakistan     | 53.965      | 0.003072       | 40.68          | 801        |
| 40   | M. E. Trescothick     | Pakistan     | 53.965      | 0.003072       | 40.68          | 801        |
| 41   | M. E. Trescothick     | Pakistan     | 53.965      | 0.003072       | 40.68          | 801        |
| 42   | M. E. Trescothick     | Pakistan     | 53.965      | 0.003072       | 40.68          | 801        |
| 43   | M. E. Trescothick     | Pakistan     | 53.965      | 0.003072       | 40.68          | 801        |
| 44   | M. E. Trescothick     | Pakistan     | 53.965      | 0.003072       | 40.68          | 801        |
| 45   | M. E. Trescothick     | Pakistan     | 53.965      | 0.003072       | 40.68          | 801        |
| 46   | M. E. Trescothick     | Pakistan     | 53.965      | 0.003072       | 40.68          | 801        |
| 47   | M. E. Trescothick     | Pakistan     | 53.965      | 0.003072       | 40.68          | 801        |
| 48   | M. E. Trescothick     | Pakistan     | 53.965      | 0.003072       | 40.68          | 801        |
| 49   | M. E. Trescothick     | Pakistan     | 53.965      | 0.003072       | 40.68          | 801        |
| 50   | M. E. Trescothick     | Pakistan     | 53.965      | 0.003072       | 40.68          | 801        |
Table 3: Ranking of top 50 bowlers in the history of Test cricket (1877 – 2011). We compare the rank of the bowlers according to their In-strength and compare them with the corresponding PageRank score, Batting average and best ever points according to ICC ratings.

| Rank | Bowler            | Country       | In-strength | PageRank Score | Bowling Average | ICC Points |
|------|-------------------|---------------|-------------|----------------|-----------------|------------|
| 1    | M. Muralitharan   | Sri Lanka     | 1838.727    | 0.081376       | 22.72           | 920        |
| 2    | S. K. Warne       | Australia     | 1600.098    | 0.037871       | 25.41           | 905        |
| 3    | G. D. McGrath     | Australia     | 1581.467    | 0.035376       | 21.64           | 914        |
| 4    | A. Kumble         | India         | 1207.115    | 0.028108       | 29.65           | 859        |
| 5    | C. A. Walsh       | West Indies   | 1206.669    | 0.028407       | 24.44           | 867        |
| 6    | C. E. L. Ambrose  | West Indies   | 1118.653    | 0.014483       | 20.99           | 912        |
| 7    | M. D. Marshall    | West Indies   | 1077.349    | 0.027349       | 20.94           | 910        |
| 8    | S. M. Pollock     | South Africa  | 1060.700    | 0.008220       | 23.11           | 909        |
| 9    | D. K. Lillee      | Australia     | 907.015     | 0.011724       | 23.92           | 884        |
| 10   | Wasim Akram       | Pakistan      | 906.455     | 0.007559       | 23.62           | 830        |
| 11   | Imran Khan        | Pakistan      | 891.679     | 0.012749       | 22.81           | 922        |
| 12   | A. A. Donald      | South Africa  | 842.499     | 0.039000       | 22.25           | 885        |
| 13   | M. Ntini          | South Africa  | 836.285     | 0.004674       | 28.82           | 863        |
| 14   | Waqar Younis      | Pakistan      | 832.86      | 0.004918       | 28.62           | 863        |
| 15   | F. R. Trueman     | England       | 791.479     | 0.034600       | 21.57           | 898        |
| 16   | N Kapil Dev       | India         | 778.960     | 0.006425       | 29.64           | 877        |
| 17   | Harbhajan Singh   | India         | 761.382     | 0.004886       | 32.22           | 765        |
| 18   | I. T. Botham      | England       | 720.371     | 0.003157       | 28.40           | 911        |
| 19   | R. G. D. Willis   | England       | 719.321     | 0.005895       | 25.20           | 837        |
| 20   | D. L. Underwood   | England       | 697.050     | 0.008028       | 25.83           | 902        |
| 21   | W. P. U. J. Vaas  | Sri Lanka     | 668.274     | 0.004674       | 28.62           | 911        |
| 22   | J. Garner         | West Indies   | 647.740     | 0.002903       | 20.97           | 896        |
| 23   | B. Lee            | Australia     | 624.158     | 0.002937       | 30.81           | 811        |
| 24   | M. A. Holding     | West Indies   | 615.905     | 0.003025       | 23.68           | 860        |
| 25   | L. R. Gibbs       | West Indies   | 607.816     | 0.010326       | 29.09           | 897        |
| 26   | R. R. Lindwall    | Australia     | 593.348     | 0.008941       | 23.03           | 897        |
| 27   | C. J. McDermott   | Australia     | 590.881     | 0.003218       | 28.63           | 794        |
| 28   | J. N. Gillespie   | Australia     | 585.951     | 0.002121       | 26.13           | 812        |
| 29   | J. B. Statham     | England       | 577.871     | 0.007935       | 24.84           | 810        |
| 30   | S. F. Barnes      | England       | 575.551     | 0.011649       | 16.43           | 932        |
| 31   | Z Khan            | India         | 574.541     | 0.002255       | 31.78           | 752        |
| 32   | A. V. Bedser      | England       | 573.140     | 0.001847       | 24.89           | 903        |
| 33   | D. L. Vettori     | New Zealand   | 558.336     | 0.003616       | 33.65           | 681        |
| 34   | A. H. Davidson    | Australia     | 531.048     | 0.004510       | 26.01           | 908        |
| 35   | M. J. Hoggard     | England       | 530.846     | 0.006146       | 30.56           | 795        |
| 36   | J. C. Laker       | England       | 522.186     | 0.004533       | 21.24           | 897        |
| 37   | G. D. McKenzie    | Australia     | 518.735     | 0.003349       | 29.78           | 846        |
| 38   | Saqlain Mushtaq   | Pakistan      | 513.114     | 0.001625       | 29.83           | 771        |
| 39   | R. Benaud         | Australia     | 512.066     | 0.003863       | 27.03           | 863        |
| 40   | C. V. Grimmett    | Australia     | 509.586     | 0.024239       | 24.21           | 901        |
| 41   | J. H. Kallis      | South Africa  | 500.176     | 0.001848       | 32.51           | 742        |
| 42   | Mohammad Asif     | Pakistan      | 499.581     | 0.001268       | 24.36           | 818        |
| 43   | R. B. Bedi        | India         | 488.933     | 0.002868       | 28.71           | 804        |
| 44   | J. M. Anderson    | England       | 486.732     | 0.002245       | 30.46           | 813        |
| 45   | A. R. Caddick     | England       | 483.088     | 0.001447       | 29.91           | 732        |
| 46   | K. R. Miller      | Australia     | 476.808     | 0.003903       | 22.97           | 862        |
| 47   | J. A. Snow        | Australia     | 468.051     | 0.002138       | 26.66           | 832        |
| 48   | D. Gough          | England       | 457.295     | 0.001287       | 28.39           | 794        |
| 49   | W. W. Hall        | West Indies   | 455.804     | 0.003022       | 26.38           | 898        |
Table 4: Ranking of top 50 bowlers in the history of ODI cricket (1971 – 2011). We compare the rank of the bowlers according to their In-strength and compare them with the corresponding PageRank score, Batting average and best ever points according to ICC ratings.

| Rank | Bowlers       | Country         | In-strength | PageRank Score | Bowling Average | ICC Points |
|------|---------------|-----------------|-------------|----------------|-----------------|------------|
| 1    | M. Muralitharan | Sri Lanka       | 607.375     | 0.170207       | 23.08           | 913        |
| 2    | Wasim Akram    | Pakistan        | 601.274     | 0.111784       | 23.52           | 850        |
| 3    | G. D. McGrath  | Australia       | 473.596     | 0.029389       | 22.02           | 903        |
| 4    | Waqar Younis   | Pakistan        | 471.019     | 0.030567       | 23.84           | 778        |
| 5    | S. M. Pollock  | South Africa    | 440.701     | 0.018813       | 24.50           | 917        |
| 6    | B. Lee         | Australia       | 437.882     | 0.020709       | 23.18           | 852        |
| 7    | W. P. U. J. C. Vaas | Sri Lanka | 426.065     | 0.019129       | 27.53           | 860        |
| 8    | Saqlain Mushtaq | Pakistan       | 381.207     | 0.011187       | 21.78           | 804        |
| 9    | A. A. Donald   | South Africa    | 331.312     | 0.011041       | 21.78           | 794        |
| 10   | M. Ntini       | South Africa    | 305.877     | 0.007624       | 24.65           | 783        |
| 11   | J. Srinath     | India           | 305.067     | 0.008372       | 28.08           | 742        |
| 12   | S. K. Warne    | Australia       | 296.573     | 0.007119       | 23.84           | 786        |
| 13   | A. Kumble      | India           | 293.592     | 0.009605       | 30.89           | 797        |
| 14   | A. B. Agarkar  | India           | 283.160     | 0.011041       | 27.45           | 845        |
| 15   | Shahid Afridi  | Pakistan        | 266.683     | 0.007999       | 33.37           | 623        |
| 16   | D. L. Vettori  | New Zealand     | 261.937     | 0.005727       | 31.48           | 788        |
| 17   | Z. Khan        | India           | 262.253     | 0.006112       | 20.03           | 709        |
| 18   | Harbhajan Singh | India         | 261.937     | 0.005727       | 31.48           | 788        |
| 19   | C. E. L. Ambrose | West Indies   | 259.694     | 0.007000       | 24.12           | 877        |
| 20   | D. Gough       | England         | 247.125     | 0.004335       | 26.42           | 767        |
| 21   | S. T. Jayasuriya | Sri Lanka    | 236.641     | 0.006771       | 36.75           | 591        |
| 22   | N. Kapil Dev   | India           | 234.427     | 0.009609       | 27.45           | 845        |
| 23   | J. H. Kallis   | South Africa    | 234.421     | 0.005161       | 31.69           | 788        |
| 24   | Abdul Razzaq   | Pakistan        | 234.380     | 0.004718       | 31.83           | 678        |
| 25   | K. D. Mills    | New Zealand     | 218.920     | 0.003573       | 25.94           | 722        |
| 26   | C. J. McDermott | Australia    | 212.171     | 0.003862       | 24.71           | 808        |
| 27   | H. H. Streak   | Zimbabwe        | 211.962     | 0.003212       | 29.82           | 717        |
| 28   | J. Garner      | West Indies     | 209.613     | 0.006778       | 18.84           | 940        |
| 29   | S. E. Bond     | New Zealand     | 208.962     | 0.002790       | 20.88           | 809        |
| 30   | C. A. Walsh    | West Indies     | 203.122     | 0.004218       | 30.47           | 801        |
| 31   | N. W. Bracken  | Australia       | 202.785     | 0.002428       | 24.36           | 805        |
| 32   | C. L. Cairns   | New Zealand     | 197.498     | 0.004749       | 32.80           | 784        |
| 33   | A. Flintoff    | England         | 192.269     | 0.002707       | 24.38           | 755        |
| 34   | J. M. Anderson | England         | 191.432     | 0.003190       | 30.83           | 687        |
| 35   | M. G. Johnson  | Australia       | 187.358     | 0.002149       | 27.45           | 724        |
| 36   | C. R. D. Fernando | Sri Lanka  | 186.151     | 0.003019       | 30.20           | 624        |
| 37   | B. K. V. Prasad | India         | 177.538     | 0.003449       | 32.30           | 692        |
| 38   | Inzam Khan     | Pakistan        | 174.633     | 0.003972       | 26.61           | 780        |
| 39   | L. Kluasner    | South Africa    | 174.271     | 0.000558       | 29.95           | 657        |
| 40   | Abdur Raazak   | Bangladesh      | 173.970     | 0.002919       | 28.12           | 675        |
| 41   | M. A. Holding  | West Indies     | 160.662     | 0.004294       | 21.36           | 875        |
| 42   | C. Z. Harris   | New Zealand     | 159.101     | 0.002170       | 37.56           | 659        |
| 43   | M. D. Marshall | West Indies     | 158.326     | 0.003466       | 26.96           | 891        |
| 44   | S. C. J. Broad | England         | 158.194     | 0.000867       | 26.95           | 701        |
| 45   | C. L. Hooper   | West Indies     | 154.591     | 0.002299       | 36.05           | 679        |
| 46   | S. L. Malinga  | Sri Lanka       | 154.017     | 0.002022       | 26.35           | 674        |
| 47   | J. N. Gillespie | Australia      | 150.864     | 0.001211       | 25.42           | 823        |
| 48   | G. B. Hogg     | Australia       | 149.910     | 0.002216       | 28.84           | 688        |
| 49   | I. K. Pathan   | India           | 148.536     | 0.000352       | 29.89           | 722        |
| 50   | S. R. Waugh    | Australia       | 147.948     | 0.002199       | 34.67           | 680        |
Figure 3: (Color online) (A) Scatter plot of between the rank positions obtained according to batting average rank and In-strength rank for Test cricket (2001 – 2011) ; Spearman correlation $\rho = 0.71$. (B) Scatter plot of between the rank positions obtained according to batting average rank and PageRank score for Test cricket (2001 – 2011) ; Spearman correlation $\rho = 0.62$. (C) Scatter plot of between the rank positions obtained according to batting average rank and In-strength rank for ODI cricket (1999 – 2011) ; Spearman correlation $\rho = 0.69$. (D) Scatter plot of between the rank positions obtained according to batting average rank and PageRank score in ODI cricket (1999 – 2011) ; Spearman correlation $\rho = 0.61$. 
Figure 4: (Color online) (A) Scatter plot of between the rank positions obtained according to bowling average rank and In-strength rank for Test cricket (1877 – 2011) ; Spearman correlation $\rho = 0.53$. (B) Scatter plot of between the rank positions obtained according to bowling average rank and PageRank score for Test cricket (1877 – 2011) ; Spearman correlation $\rho = 0.46$. (C) Scatter plot of between the rank positions obtained according to bowling average rank and In-strength rank for ODI cricket (1971 – 2011) ; Spearman correlation $\rho = -0.44$. (D) Scatter plot of between the rank positions obtained according to bowling average rank and PageRank score in ODI cricket (1971 – 2011) ; Spearman correlation $\rho = -0.34$. 

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Figure 5: (Color online) (A) Scatter plot of between the rank positions obtained according to ICC points and In-strength rank for Test cricket (1877 – 2011) ; Spearman correlation $\rho = 0.69$. (B) Scatter plot of between the rank positions obtained according to ICC points and PageRank score for Test cricket (1877 – 2011) ; Spearman correlation $\rho = 0.71$. (C) Scatter plot of between the rank positions obtained according to ICC points and In-strength rank for ODI cricket (1971 – 2011) ; Spearman correlation $\rho = 0.58$. (D) Scatter plot of between the rank positions obtained according to ICC points and PageRank score in ODI cricket (1971 – 2011) ; Spearman correlation $\rho = 0.59$. 
2000 balls bowled, George Lohmann emerge as the best bowler. Again, if we apply the qualification of at least 10 dismissals, then C. S. Marriott is the best bowler. These constraints are arbitrary and hence gauging bowler’s potential according to bowling average is not robust. The advantage of network analysis is that it doesn’t introduce these ‘constraints’ and yet provides consistent results. In such situation, in-strength and PageRank score stands out as an efficient measure of a bowler’s ability. We would like to mention that although our study includes the ‘quality’ of bowling attack or ‘quality’ of dismissal of a batsman, we don’t consider the fielding abilities or wicket-keeping abilities of the fielders. It is not possible to quantify the fielding ability of a fielder, other than by the number of catches, which is not a true measure of a fielder’s ability. Some fielders are more athletic than others. Slip fielders always have a higher chance of taking a catch than others. Again, a batsman deserves more credit if he is able to beat athletic fielders like Jonty Rhodes, Ricky Ponting or Yuvraj Singh. Secondly, a bowler’s ability is also judged by the nature of wicket. An excellent bowling performance on a batsman-friendly pitch holds greater merit than that on pitches which help bowlers. Similarly, scoring runs on difficult tracks always gets more attention than scoring runs on good batting tracks. In our analysis, due to non-availability of these informations, we didn’t include these ‘external factors’ in our analysis.

Nevertheless a network based approach could address the issue of relative performance of one player against other. Our study shows that SNA can indeed classify bowlers and batsmen based on the ‘quality’ of wickets taken or runs scored and not on the averages alone. Team selection is extremely important for any nation. SNA could be used as an objective way to aid the selection committee. A proper analysis of a player’s domestic performance would help his(her) selection in the national squad. Additionally, owners of the cash rich Indian Premier League (IPL) teams spend lots of money to hire players on a contract basis. The owners along with the coaches can identify talents based on the past ‘performance’ of a player. Potentially our study could identify the greatest batsman of all
time, based on a complete player-vs-player information, which at present we are unable to identify due to non-availability of data. Our analysis doesn’t aim at replacing the existing system of ICC player ranking, which are based on expert opinions and has been optimized and almost perfected for many years. It serves as an alternate method to refine the existing ranking scheme of players and quantify the performance of a player.

There are many additional features that could be included in the networks. For example, the networks in our analysis are static. A dynamic version of the network can be constructed following the ball-by-ball commentary and obtain a detailed analysis. Again, for batsmen there are players who score differently in different innings. There are leadership effects as well. Some players perform well under different skippers. Bowlers are categorized into different categories based on their bowling style - pacers, medium pacers and spinners. Quantifying the ‘style’ of bowling and effect of pitch conditions thus remains an open area of research. A rigorous analysis backed by a complete dataset of player-vs-player could very well answer the question - Was Sir Don Bradman the greatest ever? In our quest to judge the most successful bowler in the history of cricket, one fact stands out: M. Muralitharan remains il capo dei capi.

Acknowledgements

The author thanks the cricinfo website and icc-cricket website for public availability of data. We also gratefully acknowledge helpful discussions with R. Mukogo and R. K. Pan as well.

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