BASKETBALL GAME AS A SCALE-FREE NETWORK

Roma Siugzdaite
Institute of Mathematics and Informatics
Akademijos 4, Vilnius, LT-08663 Lithuania
E-mail: roma.siugzdaite@rst.lt

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ABSTRACT

Team sports provide a great opportunity to learn, think about, and apply complex systems concepts and methods. Understanding how individuals form effective teams has all the features of other complex systems: interactions, patterns of behaviour and the dynamics of evolutionary selection over generations leading to improvements in team effectiveness. The successful teams in different sports can teach us a lot about the effective ways of creating collective behaviour under various constraints imposed by the rules of the game [1]. From the different interactive combinations of individual players' behaviour in offence and defence and a small randomization factor ("success") final result emerges: victory or defeat.

1. INTRODUCTION

The idea of researching basketball game as a complex system came to my mind during Olympic Games 2000 in Sydney, when Lithuanian basketball team won "Dream team" from USA 94-90. A team from the small country (3mln citizens) was able to defeat the team with all professional players put together. The "Dream team" lost the meaning of this title and was called "Dreaming team". Conclusion was not surprising; I've just remembered the words of my coach Zivile Dzidolikiene: "It's a team game! So you must play all together as one: you have to know each other, to feel each other, to help each other". *Interactions* – that's the mystery of effective collective behaviour.
Later I've read a paper of prof. Yaneer Bar-Yam about complexity of team play with the descriptive analyzes of NBA final game in 2000 and playoffs in 1998. He describes *complexity as a measure of the number of possibilities*. In the context of sports, an effective defence has to meet the possible choices of the offence. Thus, the number of possible ways a player or team can create an offence is important. If a player or team has a more diverse set of offensive plays, the other side may not be able to defend against each play. The plays that it cannot defend against can be exploited. In basketball, this applies for two individuals playing one-on-one and for two teams playing against each other.

The importance of having a variety of different team plays is generally recognized in the game of basketball. Teams practice passes to set up different shots, establishing first options and, if blocked by the defence, second or third options. However, the importance of having a variety of offences extends to all aspects of the play in ways that are not always recognized.
From the different interactive combinations of individual players' behaviour in offence and defence and a small randomization factor ("success") final result emerges: victory or loss.

2. GAME RULES REVIEW

The aim of the game is to score more than the team playing against you. To get this result it needs a good team playing, understanding and supporting each other. The rules are the same to all, but every team has its own specific style, leaders, strong and weak places.

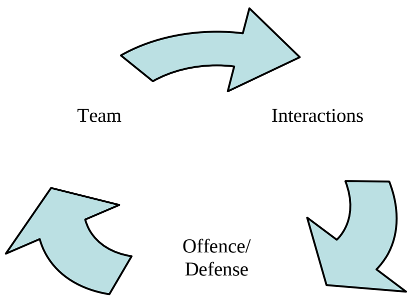


Figure 1 Simplified reinforcing diagram of a team evolution

The common scheme for all teams could be expressed by simple reinforcing diagram (Figure 1): the better team - better interactions between players; the better interactions – better offence and defence of the team; the better offence and defence – the better results, so the team is getting better and probability to win increases.

2.1. Team structure

Every team consists of 12 players, during the match 11 are registered, but only 5 of them can play at once in a field. Others can substitute the main players during a break-time. Every player has his own position (forward, centre forward, and defender). Usually team consists of 2 forwards, 2 defenders and 1 centre forward. Sometimes disposition changes depending on the team strategy.

2.2. Interactions

In basketball game there are several types of interactions. First and the simplest interaction from which game starts is passing. Intuitively it looks like the best player score more because he controls a ball longer and has more passes from others – *the game turns around him*. Let's check this hypothesis later.
The second and third one type of interactions is closely related with cooperation. During offence you are making block in order to let your team-mate shot freely. During man-on-man defence you need to change defensive players, or in zone defence you make double blocks.

2.3. Offence

The score in this game can be done by 2 or 3 points shots and 1 point free shots. The smallest 1 point shot can be done by every player after the fault done against him during the game. Free throw shots are done from the penalty box. 2 points shots can be done during all the game from the square framed with a semi-circle 6 m from the basket. And finally 3 points shots can be done from rather far distance and usually they are done by defenders. So defenders are the players that can score more than others, from more different positions, but during a game there are so many situations when score other players. Everything depends on the team strategy, the leader, ever player and a situation.

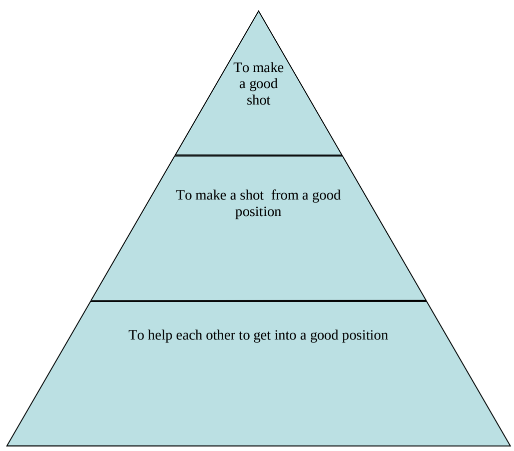


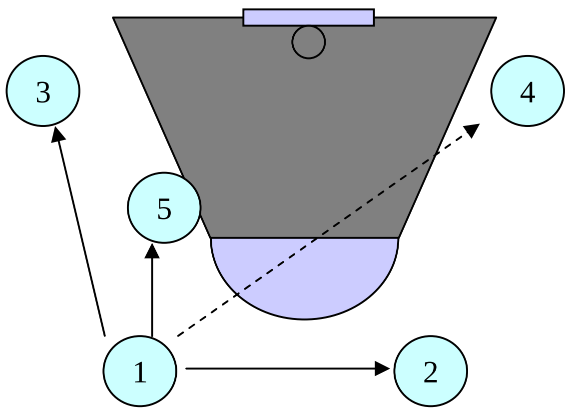
Figure 2 Diagram of making points

2.4. Defence

In general defence is of two types: man-on-man and zone defence. Defending man-on-man there is cooperation between team-mates in order to avoid blocking. Zone defence denotes players' distribution in zones and certain areas protection. Players help each other on the borders of zones.

3. GAME ANALYSIS

What kind of complexity we are looking for? How to measure interactions? How to measure number of possibilities? And what kind of statistical analyzes we can make from statistical data after match?
Passing is the most usual interaction between players we can't observe it from statistics made during match. We could count all passes during match in order to understand the most effective links. It's hard task and this purpose is possible is only watching live game (or recorded game is even better), because on TV there are replays, zooming and commercial breaks. Intuitively the most useful player should get more passes than others and so on.



Figures 2: Passes can be done by defender.

Player position	Passes (Disposed)	Passes (Received)
M Defender	3+1	3
A Defender	2+1	2+1
C Forward	2+2	2+1
W Forward	2	2
W Forward	1+1	1+1

Table 1. Team passing directions from classical disposition in Figure 3.

From this simple analysis there are two most important players arranging attacks. Defender that manages the game and central forward that plays in the closest to backboard position.
Of course it's not the dislocation that is used during every attack. It depends on the offending and also defending team, on type of attack and tasks.

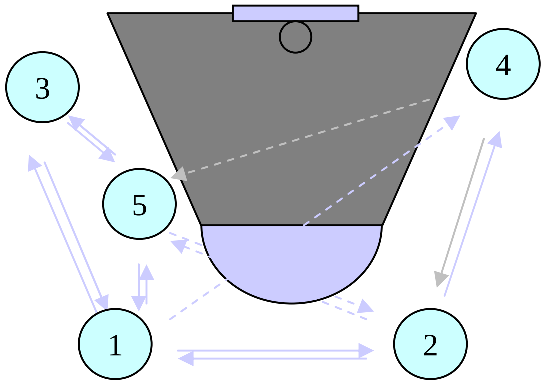


Figure 3 Standard links from classical position

4. MODELLING TEAM COMPLEXITY

Besides a simple descriptive analysis of this complex team game, there are several computer games (NBA 2000) simulating basketball. But for mathematical analysis we could use multi-agent system (MAS) modelling, where players are agents with difference roles, rules of behaviour.

The successful teams in different sports can teach us a lot about the effective ways of creating collective behaviour under various constraints imposed by the rules of the game. Because the players, sports writers, commentators, and coaches (who have particular responsibility to develop effective collective behaviours), are human beings with great insight into how the games should be played, they may also be consciously aware of key complex systems concepts.

The importance of having a variety of different team plays is generally recognized in the game of basketball. Teams practice passes to set up different shots, establishing first options and, if blocked by the defence, second or third options. However, the importance of having a variety of offences extends to all aspects of the play in ways that are not always recognized.

From the different combinations of individual players' behaviour in offence and defence and a small randomization – human factor ("success") - final result emerges: team game. If it is tuned well the way to victory is short, otherwise team game is not stable, depending on human factor.

But Interconnection and Distribution, coupled with the need for systems to represent our best interests, implies systems that can cooperate and reach agreements (or even compete) with other systems that have different interests (much as we do with other people).

4.1. Scale-free network

When comparing the random network and scale-free networks, according to Barabasi, the Poisson degree distribution of a random network means that network is similar to a highway system. In contrast, networks with a power law degree distribution (scale-free) are similar to the airline routing map.

All possible links (Fig. 4, 5) has certain weights which could be calculated empirically by many observations of different teams and various competitions. The weight is a proportion of received passes by payer and all received passes by all players during the game.

Hypothesis announces that high-scoring of a player deeply depends on the total weight of links to him (strictly speaking on the number of received passes). In this instance the more passes you can get, the more chances you have to score.

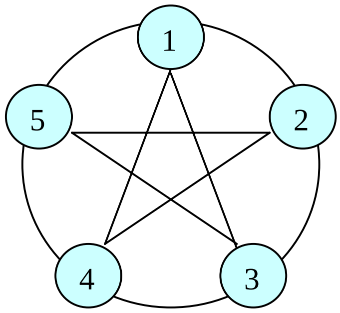


Figure 4. All possible links in starting line-up.

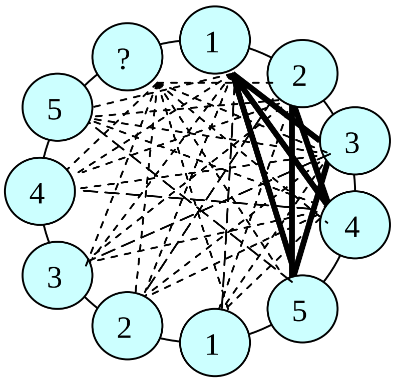


Figure 5. All possible links in a team.

There's no question of hypothesis verification analytically, because there are no similar teams; there are no similar games even with the same final result. So, in the abstract, without knowing teams, we are not able to make any realistic inferences about the final result and our hypothesis is only our sixth sense. But if we will build a model of a game based on known teams (we know positions, percentage accurateness, combinations), we could simulate a humble surrogate of the game.

4.2. Multi-agent system

How could we model basketball game? Why it is so difficult? Basketball is a very complex game with many

players, many interactions, and many combinations and with all that also accurateness takes an important place too.
The only tool able to do that comes to my mind - agent-based modelling. Agents are assumed to be autonomous, capable of making independent decision – so they need mechanisms to synchronize and coordinate their activities at run time. Agents are (can be) self-interested, so their interactions are "economic" encounters.
A multi-agent system is one that consists of a number of agents, which *interact* with one-another. In the most general case, agents will be acting on behalf of users with different goals and motivations. To successfully interact, they will require the ability to *cooperate*, *coordinate*, and *negotiate* with each other, much as players do. Our agents demonstrate balancing reactive and goal-oriented behavior:

- Agnts are reactive, responding to changing conditions in an appropriate (timely) fashion;
- Agents systematically work towards long-term goals;
- These two considerations can be at odds with one another;
- Designing an agent that can balance the two remains an open research problem.

Assume the agents in an environment may be in any of a finite set *E* of discrete states (status, positions):

$$E=\{e_0, e_1, e_2, \ldots)$$

Depending on the state agents are assumed to have a repertoire of possible actions (controlling ball, scoring, passing, blocking, fouling …) available to them:

$$Ac=\{a_0, a_1, a_2, \ldots\}$$

Interactions between two agents are linked with a subset from the set *Ac*. Still the simplified interaction rules should be established and they should be heuristic. Even if our purpose is to investigate passing, it's necessary to have several conditions to perform passing (open player, rest of attack time).

5. CONCLUSIONS AND DISCUSSION

This description illustrates the importance of complexity as a measure of the behavior of a system. Counting the number of ways one can act or react to environmental conditions is an important part of the study of complex systems in general.
There is a scarcity of methods for measuring and modeling team games complexity. A huge amount of investigations and analytical research should be done in order to understand costs of the victory.
I've made several attempts to make calculations of passing during game (Euroleague final four 2005), but my investigations finished already in the beginning of the game. It was too hard for me to follow the ball and enjoy the game. For my purpose translations have several disadvantages: you are not able to observe every player all the time, because you see zooming or replay of last moments, sometimes you have long commercials and so on. It needs a special investigation made by a group of people to avoid mistakes.
My conjecture would be the following: if we know the team, we suppose that the best player has more weighted links with team-mates. It is based on the simple logical chain that if he scores more, he makes more shots; if he makes more shots, so maybe he gets more passes. Actually, during game we have some statistics about how many times from three zones a player made shots. It carries some informant too.
In a case if we don't know the team, we think about two possibilities. I can be attacking defender, who is very mobile and can shot from every position, or central forward, who is closer to backboard and moves from one side of penalty box to another, so he is the most open player to other team-mates.
This kind of research will continue, because it is very important not only for understanding basketball or another team game, but there are many analogies in social systems that includes cooperation, coordination, negotiation or even competition.

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