

2020 年美国大学生数学建模竞赛（MCM/ICM）D 题中英版



中文：合作策略

随着社会的相互联系日益紧密，它们面临的一系列挑战也变得越来越复杂。我们依靠具有不同专业知识和不同视角的跨学科团队来解决许多最具挑战性的问题。在过去的 50 多年里，我们对团队成功的概念理解有了显著的进步，这使得更好的科学、创造性或物理团队能够解决这些复杂的问题。研究人员提出了组建团队的最佳策略、队友之间的最佳互动以及理想的领导风格。跨所有部门和领域的强大团队能够执行复杂的任务，而这些任务是无法通过个人努力或团队成员的一系列附加贡献来完成的。

在竞争性的团队运动中探索团队过程是最有用的设置之一。团队运动必须遵守严格的规则，这些规则可能包括但不限于：运动员的人数、他们的角色、运动员之间允许的接触、他们的位置和动作、得分和违规的后果。团队的成功远远不是单个球员能力的总和。相反，它是基于许多其他因素，涉及到队友在一起的表现。这些因素可能包括团队是否有多样性的技能（一个人可能快，而另一个是精确），团队如何平衡个人与集体之间的性能（明星球员可以很好的利用他们所有队友的技能），以及团队在一段时间内有效协调的能力（随着一名球员从对手抢断球，另一名球员准备进攻）。

发挥您的建模特长，哈士奇足球队的教练，已经要求您的公司，勇猛的冠军建模（ICM），帮助他了解球队的动态。特别是，教练要求您去探索球场上球员之间复杂的互动是如何影响他们的成功的。我们的目标不仅是研究直接导致得分的相互作用，而且是探索整个游戏和整个赛季的团队动态，以帮助确定可以提高下赛季团队合作的具体策略。教练要求 ICM 对成功(和失败)的结构和动力特征进行量化和形式化。哈士奇队已经提供了详细的数据^[1] 从上个赛季，包括所有 38 场比赛，他们对他们的 19 个对手(他们打每个对手两次)。总的来说，数据涵盖了 366 名球员（30 名哈士奇球员，336 名对手球员）之间的 23429 次传球，以及 59271 场比赛。

为了响应哈士奇教练的要求，您来自于 ICM 的团队应该使用提供的数据来解决以下问题：

- 为球员之间的传球建立一个网络，每个球员都是一个节点，每个传球都是球员之间的一个链接。使用您的传递网络来识别网络模式，如二元和三元结构和团队队形。还要考虑游戏中的其他结构指标和网络属性。您应该探索多个尺度，如微观（成对的）到宏观（所有球员）的互动，以及时间，如短(分钟到分钟)到长(整场比赛或整个赛季)。
- 确定反映团队合作成功（除了分数或胜利）的绩效指标，如比赛类型的多样性、球员之间的协调或贡献的分配。您还可以考虑团队过程的其他水平，例如适应性、灵活性、节奏或流畅性。弄清楚战略是普遍有效的还是取决于对手的反战略非常重要。使用您已经确定的绩效指标和团队过程的水平来创建一个模型，来捕获团队工作的结构、配置和动力方面。
- 利用从您从团队合作模式中获得见解来告诉教练，什么样的结构策略对哈士奇是有效的。根据网络分析，教练应该在下个赛季做出哪些改变来提高球队的成功。
- 您对哈士奇的分析使您能够在可控的团队运动环境中考虑群体动力学。理解哪些复杂因素使某些群体比其他群体表现更好，这对社会如何发展和创新至关重要。随着我们的社会越来越多地解决与团队有关的问题，您能概括一下您的发现，谈谈如何设计更有效的团队吗？为了开发团队绩效的通用模型，还需要捕捉团队合作的哪些其他方面呢？您提交的作品应该包括：
- 一页摘要表
- 目录
- 您的解决方案不超过 20 页，包含摘要和目录时最多 22 页。
- **注意：**参考文献和任何附录不计入页面限制，应位于完成解决方案后。您不应该使用未经授权的图像和材料，其使用受到版权法的限制。确保您在报告中引用了您的观点和材料。

附件

2020_Problem_D_DATA.zip
fullevents.csv
matches.csv
passingevents.csv
README.txt

专业名词

- **二元结构:** 涉及成对球员的关系。
- **三元结构:** 3 人一组的的关系。

参考文献

- Pappalardo, L., Cintia, P., Rossi, A. et al. A public data set of spatio-temporal match events in soccer competitions. Sci Data 6, 236 (2019).

可用资源

- Research in football (soccer) networks has led to many articles that discuss related topics. A few articles are listed below. You are not required to use any of these sample articles in your solution, nor is it a comprehensive list. We encourage teams to utilize any journal article that supports their approach to the problem.
- Buldú, J.M., Busquets, J., Echegoyen, I. et al. (2019). Defining a historic football team: Using Network Science to analyze Guardiola's F.C. Barcelona. Sci Rep, 9, 13602.
- Cintia, P., Giannotti, F., Pappalardo, L., Pedreschi, D., & Malvaldi, M. (2015). The harsh rule of the goals: Data-driven performance indicators for football teams. 2015 IEEE International Conference on Data Science and Advanced Analytics (DSAA), 1-10, 7344823.
- Duch J., Waitzman J.S., Amaral L.A.N. (2010). Quantifying the performance of individual players in a team activity. PLoS ONE, 5: e10937.
- GÜRSAKAL, N., YILMAZ, F., ÇOBANOĞLU, H., ÇAĞLIYOR, S. (2018). Network Motifs in Football. Turkish Journal of Sport and Exercise, 20 (3), 263-272.

As societies become more interconnected, the set of challenges they face have become increasingly complex. We rely on interdisciplinary teams of people with diverse expertise and varied perspectives to address many of the most challenging problems. Our conceptual understanding of team success has advanced significantly over the past 50+ years allowing for better scientific, creative, or physical teams to address these complex issues. Researchers have reported on best strategies for assembling teams, optimal interactions among teammates, and ideal leadership styles. Strong teams across all sectors and domains are able to perform complex tasks unattainable through either individual efforts or a sequence of additive contributions of teammates.

One of the most informative settings to explore team processes is in competitive team sports. Team sports must conform to strict rules that may include, but are not limited to, the number of players, their roles, allowable contact between players, their location and movement, points earned, and consequences of violations. Team success is much more than the sum of the abilities of individual players. Rather, it is based on many other factors that involve how well the teammates play together. Such factors may include whether the team has a diversity of skills (one person may be fast, while another is precise), how well the team balances between individual versus collective performance (star players may help leverage the skills of all their teammates), and the team's ability to effectively coordinate over time (as one player steals the ball from an opponent, another player is poised for offense).

In light of your modeling skills, the coach of the Huskies, your home soccer (known in Europe and other places as football) team, has asked your company, Intrepid Champion Modeling (ICM), to help understand the team's dynamics. In particular, the coach has asked you to explore how the complex interactions among the players on the field impacts their success. The goal is not only to examine the interactions that lead directly to a score, but to explore team dynamics throughout the game and over the entire season, to help identify specific strategies that can improve teamwork next season. The coach has asked ICM to quantify and formalize the structural and dynamical features that have been successful (and unsuccessful) for the team. The Huskies have provided data [1] detailing information from last season, including all 38 games they played against their 19 opponents (they played each opposing team twice). Overall, the data covers 23,429 passes between 366 players (30 Huskies players, and 336 players from opposing teams), and 59,271 game events.

To respond to the Huskie coach's requests, your team from ICM should use the provided data to address the following:

- Create a network for the ball passing between players, where each player is a node and each pass constitutes a link between players. Use your passing network to identify network patterns, such as dyadic and triadic configurations and team formations. Also consider other structural indicators and network properties across the games. You should explore multiple scales such as, but not limited to, micro (pairwise) to macro (all players) when looking at interactions, and time such as short (minute-to-minute) to long (entire game or entire season).
- Identify performance indicators that reflect successful teamwork (in addition to points or wins) such as diversity in the types of plays, coordination among players or distribution of contributions. You also may consider other team level processes, such as adaptability, flexibility, tempo, or flow. It may be important to clarify whether strategies are universally effective or dependent on opponents' counter-strategies. Use the performance indicators and team level processes that you have identified to create a model that captures structural, configurational, and dynamical aspects of teamwork.
- Use the insights gained from your teamwork model to inform the coach about what kinds of structural strategies have been effective for the Huskies. Advise the coach on what changes the network analysis indicates that they should make next season to improve team success.
- Your analysis of the Huskies has allowed you to consider group dynamics in a controlled setting of a team sport. Understanding the complex set of factors that make some groups perform better than others is critical for how societies develop and innovate. As our societies increasingly solve problems involving teams, can you generalize your findings to say something about how to design more effective teams? What other aspects of teamwork would need to be captured to develop generalized models of team performance?

Your submission should consist of:

- One-page Summary Sheet
- Table of Contents
- Your solution of no more than 20 pages, for a maximum of 22 pages with your summary and table of contents.
- note: Reference List and any appendices do not count toward the page limit and should appear after your completed solution. You should not make use of unauthorized images and materials whose use is restricted by copyright laws. Ensure you cite the sources for your ideas and the materials used in your report.

Attachment

2020_Problem_D_DATA.zip
 full_events.csv
 matches.csv
 passing_events.csv
 README.txt

Glossary

- **Dyadic Configurations:** relationships involving pairs of players.
- **Triadic Configurations:** relationships involving groups of three players.

Cited Reference

- Pappalardo, L., Cintia, P., Rossi, A. et al. A public data set of spatio-temporal match events in soccer competitions. *Sci Data* 6, 236 (2019).

Optional Resources

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- Cintia, P., Giannotti, F., Pappalardo, L., Pedreschi, D., & Malvaldi, M. (2015). The harsh rule of the goals: Data-driven performance indicators for football teams. 2015 IEEE International Conference on Data Science and Advanced Analytics (DSAA), 1-10, 7344823.
- Duch J., Waitzman J.S., Amaral L.A.N. (2010). Quantifying the performance of individual players in a team activity. *PLoS ONE*, 5: e10937.
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