
SportsXR - Immersive Analytics in Sports

Tica Lin

Harvard University
Cambridge, MA 02138, USA
mlin@g.harvard.edu

Yalong Yang

Harvard University
Cambridge, MA 02138, USA
yalongyang@g.harvard.edu

Johanna Beyer

Harvard University
Cambridge, MA 02138, USA
jbeyer@g.harvard.edu

Hanspeter Pfister

Harvard University
Cambridge, MA 02138, USA
pfister@g.harvard.edu

Abstract

We present our initial investigation of key challenges and potentials of immersive analytics (IA) in sports, which we call SportsXR. Sports are usually highly dynamic and collaborative by nature, which makes real-time decision making ubiquitous. However, there is limited support for athletes and coaches to make informed and clear-sighted decisions in real-time. SportsXR aims to support situational awareness for better and more agile decision making in sports. In this paper, we identify key challenges in SportsXR, including data collection, in-game decision making, situated sport-specific visualization design, and collaborating with domain experts. We then present potential user scenarios in training, coaching, and fan experiences. This position paper aims to inform and inspire future SportsXR research.

Author Keywords

Immersive analytics; sport analytics; visual analytics; information visualization.

CCS Concepts

•Human-centered computing → Mixed / augmented reality; Virtual reality; Visualization; Human computer interaction (HCI);

Introduction

Immersive Analytics (IA) builds upon novel immersive technologies and extends data visualization and analytics ca-

Permission to make digital or hard copies of part or all of this work for personal or classroom use is granted without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page. Copyrights for third-party components of this work must be honored. For all other uses, contact the owner/author(s).

Copyright held by the owner/author(s).
CHI'20, April 25–30, 2020, Honolulu, HI, USA
ACM 978-1-4503-6819-3/20/04.
<https://doi.org/10.1145/3334480.XXXXXXX>



Figure 1: A simulated basketball fan experience with player statistics shown in AR.



Figure 2: Interactive play sketching with synthesized defenses by Seidl et al. [12].

pabilities beyond traditional desktop workspaces. For example, IA can facilitate the exploration of heterogeneous sports datasets by making use of large display spaces, providing multi-sensory interfaces, promoting expert collaboration, and enabling situated analytics. Situating the visualization right in the context of the data and events eliminates the gap between people, data, and tools [14]. Potential applications of immersive analytics cover a wide range of domains, such as life and health sciences, construction site management, supply chain, and factory planning [8]. Immersive analytics in sports has received relatively low attention so far. However, due to its highly collaborative and strategic nature, sports have a huge potential for immersive analytics.

Sports generate a huge amount of heterogeneous data, such as real-time positions of players, physiological measurements of players, tactical trajectories, and scouting insights. Current sports data visualization research mostly focuses on visual analytics systems on traditional 2D screens [9], which are usually used off-line. However, in practice, there is a huge demand for in-game decision making. Thus, a more situated and user-centered approach to visualize and analyze sports data is required to bring real-time analytics to decision-makers (e.g., players, coaches, and team executives). Applying IA to sports can engage a broader audience with embodied analytic capabilities and enable data-driven decision making in various use cases. For example, a real-time overlay of a player's box score and an intuitive data analysis interface on a heads-up display could bring fan engagement to the next level (see Fig. 1).

In this paper, we present the challenges and potentials of applying IA to sports to eliminate the gap between sports data, people, and tools from the perspectives of IA researchers. We, furthermore, outline a vision of SportsXR in three spe-

cific user scenarios that empower athletes, coaches, and fans.

Related Research Fields

SportsXR builds upon a variety of research fields. At its heart, SportsXR integrates sports analytics with situated analytics. Situated analytics is a subset of the larger field of immersive analytics, which focuses on applying embodied display and interaction techniques (e.g., augmented and virtual reality) for data visualization and analytics. Situated analytics, in addition, emphasizes the use of augmented reality to link abstract visual representations to objects in the physical world.

Sports Analytics

Sports analytics has become popular with the success of the MLB Moneyball story in 2002. Oakland Athletics General Manager Billy Beane, with a limited budget, used sabermetrics to draft undervalued players and subsequently won games against rich teams like the New York Yankees [7]. The recent explosion of computational power, motion capture technology, and statistical methods make advanced sports analytics feasible in many scenarios. This includes game outcome prediction, measurement and evaluation of player performance, analysis of rules and adjudication, and within-game strategy.

However, these fully automatic methods do not integrate the knowledge of decision-makers (i.e., coaches, scouts, and managers) in an effective way [1]. Data visualization and visual analytics have been integrated into the sports analytics workflow to enable human-in-the-loop analytics. For example, Seidl et al. [12] use NBA game tracking data to perform data-driven ghosting defense prediction. They also offer a tablet-based interface for coaches to perform real-time strategy planning (see Fig. 2). Wu et al. [17] create a



Figure 3: Interactive visualization of table tennis data by Wu et al. [17]. © 2018 IEEE, reprinted with permission.



Figure 4: An in-situ collaborative scenario demonstrated by Yang et al. [18]. © 2019 IEEE, reprinted with permission.

holistic visualization system for table tennis match data and empower domain experts to find unnoticed patterns (see Fig. 3). Perin et al. [9] have compiled a comprehensive survey of these systems. However, there is still a clear demand for more natural and transparent interface design to intuitively interact with sports data to perform meaningful data analytics and prediction.

Immersive and Situated Analytics

Immersive analytics leverage new display and interaction techniques, such as AR/VR headsets, for visual analytics [8]. Compared to traditional displays, AR/VR headsets can render very large displays at low cost with a high degree of portability compared to wall displays and CAVEs. Therefore, AR/VR headsets can create immersion through situated and collaborative visualization. This opens up opportunities for direct interaction with visuals that are radically different from desktop computing paradigms. Situated analytics is a form of in-situ interactive visual analysis. In situated analytics, visual representation of information is immediately linked to physical objects to facilitate sense-making [15] (e.g., see Fig. 4).

VR for sports training has been preliminarily explored, e.g., for basketball and baseball: Tsai et al. [16] use a VR simulation to train basketball players' decision-making skills, and Zou et al. [19] visualize simulated pitch and bat swing data in VR to improve a baseball player's batting eye. Applying AR in sports is largely unexplored and can bring unique opportunities for the integration of digital information and physical movements.

Industrial Sports Analytic Platforms

There are several innovative commercial products applying AR/VR for sports training, coaching, and fan experiences. STRIVR [13] uses VR as an immersive learning platform to simulate real game scenarios to train decision making

and mental preparation for professional football players, skiers, and basketball players. Rezzil [10] provides similar VR training with coaching and analytic features for professional soccer players. Second Spectrum [11] experiments on player tracking and AR features for visual information augmentation on broadcasting and video re-play. CourtVision [4] provides information and stats overlays in AR for enhancing live sports viewing experiences for NBA basketball fans within minutes of the live game. However, those applications only cover some sub-areas of SportsXR, leaving many other areas still being unexplored.

Challenges

We have identified four main challenges in SportsXR research: 1) sports data collection; 2) in-game decision making; 3) situated sports-specific visualization design; and 4) collaboration with domain experts.

Sports Data Collection and Extraction

Sports data are inherently complex. Typical datasets contain a combination of heterogeneous, multi-dimensional, and unstructured data. Examples include box score data, tracking data, scouting reports, game video clips, players' mentality, and many other qualitative metrics [9]. Standards for data collection need to be enforced to ensure that the collected data is unbiased and compatible with the subsequent analytic workflow. Meeting these standards requires considerable efforts for real-time data recording, pre-processing, data cleaning, and formatting. Furthermore, in the context of situated and in-game analytics, data often needs to be extracted from video feeds and live sensors. This, in turn, requires state-of-the-art computer vision techniques to track game objects and players. For example, basketball analytics collects dynamic movement data of all players and detects shot types and defensive vs. offensive tactics to evaluate the performance of each player, while

baseball analytics focuses more on pitch type and base rate to evaluate player value.

The first challenge, therefore, lies in identifying, collecting, and extracting various data required for different sports and contexts.

In-game Decision Making

Research on optimal statistical models and visualization tools for game prediction and evaluation in various sports has seen a huge growth in the last decade. However, current sports analytics only occur asynchronously in the hands of data scientists, leading to inefficient communication and inaccurate decision making on the athlete side. By bringing in-situ analytic power to domain experts such as coaches and athletes, immersive analytics will play an important role in eliminating the gap between data-driven strategies and executions.

The second challenge, therefore, lies in making analytics models not only understandable to coaches and athletes but to also enable fast in-game and in-situ analytics.

Situated Sport-specific Visualization Design

One distinguishing feature of SportsXR is that analytics need to be performed in-situ and need to be updated dynamically to maximize its impact. However, coaches and athletes primarily have to focus on real-world movements and events. Thus, the visualizations in SportsXR need to be situated, highly dynamic, concise, and context-dependent to play an auxiliary role. For example, a basketball coach using SportsXR to evaluate offensive options needs different analytics based on a player's location and a defender's movement. A spatial shot percentage map of the ball handler might be helpful when the defense is wide open, but when the player is being contested, the shot percentages of other shooters on the team are more important. Deciding

when and how to change the presented data to optimally support data-driven decision making will be a key design consideration in SportsXR.

The third challenge, therefore, lies in defining the context-dependent factors based on real-world events to decide how to present and interact with dynamic situated data.

Collaboration with Domain Experts

User-centered design has been proven to be an effective way of engaging end-users [6]. Batch et al. [2] worked closely with economic data analysts to integrate immersive visualization into their actual workflow. In contrast, domain experts in sports rarely perform data analytics themselves but make in-game decisions based on experience rather than based on data. To understand the decision-making workflow of coaches and athletes, researchers first need to gain in-depth domain knowledge. Based on this domain knowledge, they can then identify and extract analytic components from the heuristic insights in order to improve the accuracy of their decision making. Furthermore, researchers need to educate their sports collaborators on analytics and visualization methods, as well as introduce them to novel AR interfaces for situated analytics.

In our current research project, we collaborate closely with both Harvard Men's and Women's Basketball teams to gather first-hand expert knowledge. Building personal sport expertise and working with data analysts on an interdisciplinary sports analytics team can lead to more effective collaborations with coaches and players.

The fourth challenge, therefore, lies in establishing an effective collaboration between immersive analytics researchers and sports experts.

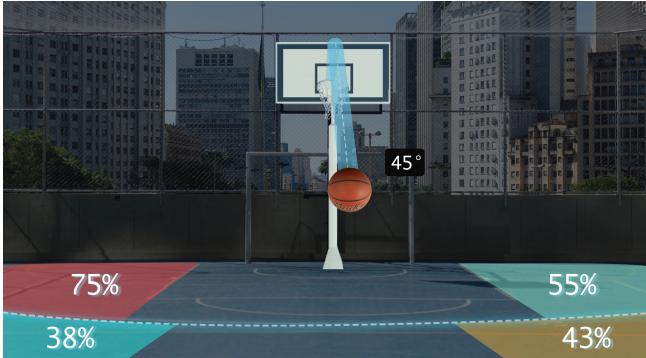


Figure 5: Basketball shooting training in SportsXR.

Potential User Scenarios

We have identified the following SportsXR scenarios: athlete training, coaching, and fan experience.

Training

Technological innovations in sports training are not just crucial to improve training effectiveness with instant performance feedback and overall body condition monitoring, but also to reduce injuries and to excel former records. Most data collected during training are interpreted and communicated to athletes by their coaches. However, embodied data analytics can empower athletes with the ability to self-evaluate and modify their techniques in real-time. Furthermore, immersive visualizations can enhance the collaboration between coaches and athletes by embedding the visuals spatially into the real world (see Fig. 5). A pioneer example of this was demonstrated by Eliud Kipchoge breaking the 2-hour marathon barrier with the help of a projected pacing visualization in real-time [3].

Coaching

So far, sports analytics has had its highest impact on coaching decision making. Data scientists in the backroom apply advanced machine learning and computer vision to convert video and statistical data into strategic insights. On top of the advanced statistical models that track detailed winning factors in players' performance, the close collaboration between analysts and coaches has been the key factor for the successful team rebuild of the NBA Philadelphia 76ers [5]. However, for many teams and individual sports like tennis or track-and-field, employing a professional data analytics team is unfeasible. The spatial immersion and in-situ decision making of situated analytics allow SportsXR to embed analytics into the coaching workflow for a seamless integration of analytic and coaching insights.

Fan Experience

Immersive technologies have gradually become a big part of social experiences, such as AR filters on Snapchat or Instagram and VR game watching of the FIFA World Cup. To bring fan experience to the next level, personal storytelling through data visualization and content creation plays an important role in deepening a sports fan's engagement. SportsXR can add digital information overlays in real-time, and provide a more engaging interactive experience such as video annotation, dynamic data lookup, performance comparison, and customized view manipulation. The design challenges for immersive visualization and interaction, in this case, are largely unsolved research questions.

Conclusions

In this paper, we discuss the trends and challenges IA research communities are facing in the new research field of SportsXR. We have outlined potential research areas and encourage the exploration of SportsXR applications in training, coaching, and fan experience. Building upon the con-

tinuous research efforts in immersive analytics, SportsXR presents unique challenges for research: First, sports data collection is challenging due to complex data types and contexts. Second, analytics models need to be suitable for fast, situated decision making by athletes and coaches. Third, SportsXR development requires the design of novel, sports-specific, dynamic, and situated data visualization and interaction methods, and fourth, SportsXR relies on a close collaboration between researchers and sports domain experts. We hope that SportsXR will eliminate gaps between analytic and athletic insights, propel innovation in sports, and make sports analytics available to larger audiences.

Acknowledgments

We wish to thank Coach Kathy Delaney-Smith, Mike Roux, Mark Kaliris, and Lindsay Werner at Harvard Women's Basketball, and Mike Sotsky and Casey Brinn at Harvard Men's Basketball for their time and expertise. This research is supported in part by King Abdullah University of Science and Technology (KAUST) and the KAUST Office of Sponsored Research (OSR) award OSR-2015-CCF-2533-01.

REFERENCES

- [1] Benjamin C Alamar. 2013. *Sports Analytics: A Guide for Coaches, Managers, and Other Decision Makers*. Columbia University Press.
- [2] Andrea Batch, Andrew Cunningham, Maxime Cordeil, Niklas Elmquist, Tim Dwyer, Bruce H. Thomas, and Kim Marriott. 2019. There Is No Spoon: Evaluating Performance, Space Use, and Presence with Expert Domain Users in Immersive Analytics. *IEEE Transactions on Visualization and Computer Graphics* 26, 1 (2019), 536–546. DOI: <http://dx.doi.org/10.1109/TVCG.2019.2934803>
- [3] Kim Bellware. 2019. Lasers, rabbits and new Nikes: How the 2-hour marathon barrier was broken. (2019). <https://www.washingtonpost.com/sports/2019/10/15/lasers-rabbits-new-kicks-how-hour-marathon-barrier-was-broken/>
- [4] CourtVision. 2020. (2020). <https://www.clipperscourtvision.com/>
- [5] Marcus Hayes. 2018. Analytics-driven Sixers ride the numbers to NBA playoffs. (2018). <https://www.inquirer.com/philly/sports/sixers/sixers-76ers-philadelphia-analytics-process-numbers-nba-playoffs-miami-heat-brett-brown-bryan-colangelo-20180418.html>
- [6] Heidi Lam, Melanie Tory, and Tamara Munzner. 2018. Bridging from Goals to Tasks with Design Study Analysis Reports. *IEEE Transactions on Visualization and Computer Graphics* 24, 1 (Jan. 2018), 435–445. DOI: <http://dx.doi.org/10.1109/TVCG.2017.2744319>
- [7] Michael Lewis. 2004. *Moneyball: The Art of Winning an Unfair Game*. W. W. Norton & Company.
- [8] Kim Marriott, Falk Schreiber, Tim Dwyer, Karsten Klein, Nathalie Henry Riche, Takayuki Itoh, Wolfgang Stuerzlinger, and Bruce H. Thomas (Eds.). 2018. *Immersive Analytics*. Lecture Notes in Computer Science, Vol. 11190. Springer International Publishing, Cham. DOI: <http://dx.doi.org/10.1007/978-3-030-01388-2>
- [9] C. Perin, R. Vuillemot, C. D. Stolper, J. T. Stasko, J. Wood, and S. Carpendale. 2018. State of the Art of Sports Data Visualization. *Computer Graphics Forum* 37, 3 (June 2018), 663–686. DOI: <http://dx.doi.org/10.1111/cgf.13447>
- [10] Rezzil. 2020. (2020). <https://rezzil.com/>

- [11] Second Spectrum. 2020. (2020).
<https://www.secondspectrum.com/>
- [12] Thomas Seidl, Aditya Cherukumudi, Andrew Hartnett, Peter Carr, and Patrick Lucey. 2018. Bhostgusters: Realtime interactive play sketching with synthesized nba defenses. In *Proceeding of the 12th MIT Sloan Sports Analytics Conference, Boston, MA*. Boston: MIT.
- [13] STRIVR. 2020. (2020). <https://www.strivr.com/>
- [14] T Chandler, M Cordeil, T Czauderna, T Dwyer, J Glowacki, C Goncu, M Klapperstueck, K Klein, K Marriott, F Schreiber, and E Wilson. 2015. Immersive Analytics (*2015 Big Data Visual Analytics (BDVA)*). 1 8. DOI:
<http://dx.doi.org/10.1109/bdva.2015.7314296>
- [15] Bruce H. Thomas, Gregory F. Welch, Pierre Dragicevic, Niklas Elmqvist, Pourang Irani, Yvonne Jansen, Dieter Schmalstieg, Aurélien Tabard, Neven A. M. ElSayed, Ross T. Smith, and Wesley Willett. 2018. Situated Analytics. In *Immersive Analytics*, Kim Marriott, Falk Schreiber, Tim Dwyer, Karsten Klein, Nathalie Henry Riche, Takayuki Itoh, Wolfgang Stuerzlinger, and Bruce H. Thomas (Eds.). Vol. 11190. Springer International Publishing, Cham, 185–220. DOI:
http://dx.doi.org/10.1007/978-3-030-01388-2_7
- [16] Wan-Lun Tsai, Li-wen Su, Tsai-Yen Ko, Cheng-Ta Yang, and Min-Chun Hu. 2019. Improve the Decision-making Skill of Basketball Players by an Action-aware VR Training System. In *2019 IEEE Conference on Virtual Reality and 3D User Interfaces (VR)*. IEEE, Osaka, Japan, 1193–1194. DOI:
<http://dx.doi.org/10.1109/VR.2019.8798309>
- [17] Yingcai Wu, Ji Lan, Xinhuan Shu, Chenyang Ji, Kejian Zhao, Jiachen Wang, and Hui Zhang. 2017. iTTVIs: Interactive Visualization of Table Tennis Data. *IEEE Transactions on Visualization and Computer Graphics* 24, 1 (2017), 709–718. DOI:
<http://dx.doi.org/10.1109/tvcg.2017.2744218>
- [18] Yalong Yang, Tim Dwyer, Bernhard Jenny, Kim Marriott, Maxime Cordeil, and Haohui Chen. 2019. Origin-Destination Flow Maps in Immersive Environments. *IEEE Transactions on Visualization and Computer Graphics* 25, 1 (2019), 693–703. DOI:
<http://dx.doi.org/10.1109/tvcg.2018.2865192>
- [19] Liyuan Zou, Takatoshi Higuchi, Haruo Noma, Lopez-Gulliver Roberto, and Tadao Isaka. 2019. Evaluation of a Virtual Reality-based Baseball Batting Training System Using Instantaneous Bat Swing Information. In *2019 IEEE Conference on Virtual Reality and 3D User Interfaces (VR)*. IEEE, Osaka, Japan, 1289–1290. DOI:
<http://dx.doi.org/10.1109/VR.2019.8798041>