This workshop proposal was accepted by IEEE VIS 2024.

First-Person Visualizations for Outdoor Physical Activities: Challenges and Opportunities

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1 Workshop Description

This half-day workshop will gather researchers and practitioners interested in first-person visualizations for outdoor physical activities. Given the unexplored nature of the topic, the goal of this first workshop is to collect speculative designs informed by experience and expertise. Participants will mainly submit fictional case studies in the forms of illustrated submissions along with a statement that demonstrates their knowledge/expertise of the case study. Our goal is to build on these speculative designs to i) explore the space of first-person visualizations for outdoor physical activities and ii) derive a research agenda for the visualization community. We envision this output to take the form of a publication of which workshop participants will be invited to become co-authors.

2 Motivation - Why is This Workshop Necessary and what related scientific initiatives exist?

In the visualization community, and more specifically in the IEEE VIS/TVCG community, sports visualization and visual analytics has gained traction in the past decade, and there are now several papers and posters presented at VIS on the topic each year. There has been a workshop at VIS 2013 on sports visualization[1]. Since then, many papers have been published and presented at VIS. In 2022 there were two entire paper session named "Sports Data Analysis and Visualization", and in 2023 another one named "Sports and Spatial Management". Figure 1 and Figure 2 show the growing interest in the topic and its impact in the community, particularly in the past 10 years. This research in sports visualization has provided tools for journalists, experts, enthusiasts, and so on for sports as varied as soccer, rugby, table tennis, basketball, baseball, swimming, sailing and skiing (e.g., [13,35,38,47,57]), and a survey on Sports Visualization has synthesized this emerging body of work in 2018 [37].

Past research in visualization, however, has been focusing on designing and developing visual design and visual analytics tools for analysis of sports event by people who are not the actors of the sport, such as a tool to visually explore shots in NBA or soccer across an entire season, or a dashboard for real-time analysis of strategies and events of rugby games. Recent work in the emerging area of SportsXR [8,25,26,28,29] (immersive analytics in sports) has taken a step forward in combining modern technology and sensors with innovative immersive visualization techniques to provide (real-time) access to information during sports events, such as statistics and likelihood of events in team sports.

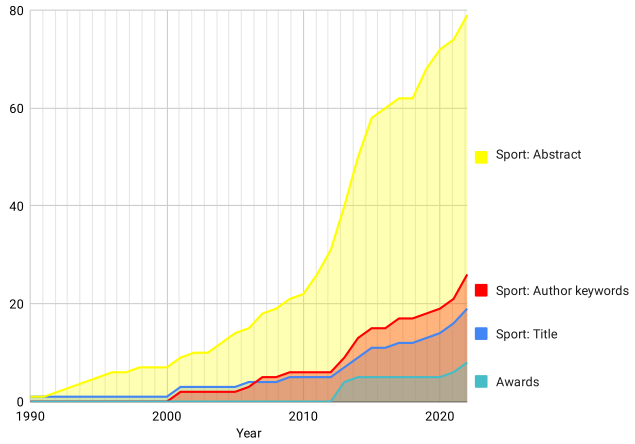

Figure 1: Cumulative number of VIS/TVCG papers with "Sport" in Title, Abstract and Author keywords, and number of those with awards. According to VisPubData [17], 1990-2022.

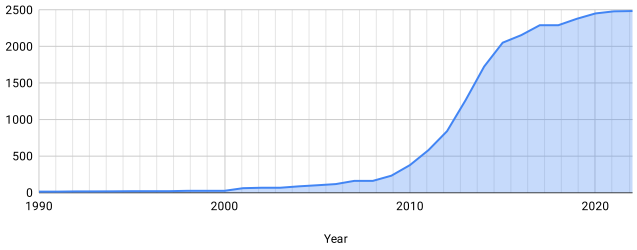

Figure 2: Cumulative internal (VIS/TVCG) number of citations for papers with "Sport" in one of Title, Abstract or Author keywords. According to VisPubData [17], 1990-2022.

In contrast to the topic of this workshop, this past research is concerned with providing third-person visualization tools (e.g., for viewers, analysts, coaches, journalists, etc..). The topic of first-person visualization support for people to use while they are performing sports and physical activities has been widely ignored by the visualization community thus far, probably because this is a topic that intersects visualization and multiple HCI disciplines concerned with wearables, ubiquitous computing, social computing, and more.

In the meantime, the broad HCI community has embraced emerging technology such as wearables, VR/AR/XR and sensors to both study HCI in the context of sports and physical activities, and to study sports and physical activities through the lens of HCI. There was a CHI 2014 workshop on HCI and sports [33] that established

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[1] https://workshop.sportvis.com/

the research area within the HCI community as they started the discussion on "what HCI can contribute to the sports domain, as well as what HCI can gain from studying sports". Several subsequent workshops took place. For example, the CHI 2021 workshop on embodied interaction in sports [45] focused on exploring how interactive systems can enhance sports experiences beyond performance. The MobileHCI 2022 workshop on new trends in HCI and sports [32] focused on portable technologies for sports. CHI 2024 is seeing a workshop dedicated to cycling and HCI[2].

There is a need to initiate the discussion of first-person, athlete-centric visualization research as not only yet another application domain, but a domain that will bring unique research questions to the field of visualization. Indeed, we already identify that understanding how to visualize data while performing a strenuous activity will raise at least the following challenges:

- **Design and technology challenges**, such as how might we leverage emerging wearable technology such as AR glasses? How to design visualizations for such devices? How to consider the outdoor environment in the design of such interfaces? What should new technology support and enable?
- **Interaction challenges**, such as how to interact with visualizations in these non-typical office or lab environments? Can multi-modal approaches to interaction be leveraged and how?
- **Perceptual and cognitive challenges**, such as how might visualization be potentially distracting and negatively affecting people's main focus of performing their activity? How might attention, perception and cognition be affected by fatigue, effort, and concentration? How do people perceive, interpret, and make decisions about data, under limited attentional capacity?
- **Evaluation challenges**, such as how to collect participant data? How to design studies while maintaining realism? What protocols, sensors and other study instruments are appropriate and need to be developed? What tasks need to be supported?

To identify and address these challenges, we will build on emerging visualization research topics concerned with immersive analytics [7, 31], situated visualizations [3] and embedded data representations [49], mobile visualizations [23, 24] visualizations in motion [18, 56, 57] and SportsXR [8, 25, 26, 28, 29].

3 Workshop Goals

The goals of this workshop are:

1. to gather researchers and practitioners interested in this new topic,
2. to collect speculative designs informed by experience and expertise, and
3. to establish a research agenda on first-person visualizations for outdoor physical activities for the visualization community to tackle.

4 Submission Format

The main submission type for this workshop is speculative designs for a specific case study along with a statement that demonstrates their knowledge/expertise of the case study, and visual illustrations of these speculative designs and case study. The intention is that these will resemble annotated pictorial submissions. Secondary types of accepted submissions are position papers and reflections (on specific case studies).

We will encourage submissions to be made using the official IEEE Conferences template, but submissions in any format will be accepted, as long as they are submitted as a pdf file. Recommended submission length will be between 1000 and 2500 words with any number of accompanying figures, but longer submissions will be considered.

[2] https://exertiongameslab.org/workshops-events/chi-2024-cyclinghci

5 Workshop Format and Planned Activities

This will be a half-day hybrid workshop. To best leverage the workshop format, we will minimize the amount of time dedicated to talks and presentations and maximize the amount of time dedicated to active group work and discussions. For this reason, we do not plan to include a keynote speaker and will have only short presentations from authors.

Presentations and Introduction of Challenges: Each accepted submission will be given 3-5min to present (depending on number of accepted submissions), followed by a Q&A session. After all accepted submissions have been presented, we will present the audience with an initial list of challenges we will have identified before the workshop, based on submissions and our own reflections. We will ask the audience to add/edit these challenges, and will then ask the audience to think about these during the coffee break.

Hands-on session: We will invite the workshop participants to self-select an identified challenge they are particularly interested in, and to form groups based on interest. We will provide templates that each formed group will fill during that session, highlighting the challenge, an exemplar case study, and resulting research opportunities. Subsequently, each group will report their discussion for not longer than 5 minutes to the entire workshop. Given the hybrid format of the workshop, we will form both in-person participant groups and remote participant groups, but will avoid mixed groups.

Wrap-up discussion & next steps: To end the workshop, we will convene a structured discussion informed by the hands-on session. We will also discuss the concrete next step of writing a research paper based on the workshop and invite authors and attendees to participate. After the workshop, a voluntary workshop lunch will be planned for in-person attendees to encourage community building.

6 Tentative Schedule

Assuming a 3h long half day workshop with a 30 minute long break, the planned schedule for the workshop is as follows (the following is assuming a morning workshop starting at 9am):

- 09:00–09:15 **Opening and outline**
- 09:15–10:15 **Presentations and Introduction of Challenges**
- *10:15–10:45* ***Coffee Break***
- 10:45–11:30 **Hands-on Session in Groups**
- 11:30–12:00 **Wrap-up discussion & next steps**
- 12:00 **Voluntary Workshop Lunch**

7 Workshop Organization and Timeline

We will advertise widely to several communities, including InfoVis (via infovis mailing list), VIS (via VIS email blasts and the VIS Researchers slack group), VR (via the IEEE VR mailing list), HCI (via the sigchi mailing list and the HCIResearchers slack group), as well as through our personal social networks (Twitter/X, Mastodon, Facebook, etc..).

Workshop submissions will be reviewed internally by the workshop organizers. We do not plan on having a pool of reviewers or a program committee beyond the organizers, given that the review process will be lightweight, as follows:

1. All workshop organizers read all submissions that they are not in conflict with,
2. All non-conflicted organizers indicate if a submission:
3. (a) is of the requested submission types,

(b) is on topic and likely to stimulate interest and discussion,

(c) is of reasonable presentation quality.

4. All submissions for which a majority of non-conflicted reviewers answer 'yes' to these three questions will be accepted.

We expect this lightweight review process will be sufficient, given that authors are not asked to formulate a research contribution in their submission. We will follow-up with rejected submissions to offer the authors an opportunity to revise and resubmit - something that is made feasible thanks to our flexible timeline and submission format. In the case that fewer than two workshop organizers are not in conflict with a submission, then we will seek external reviewers to handle these cases.

The timeline for the workshop organization is as follows:

- March 20, 2023: **Call for Participation**
- July 31, 2023: **Submission Deadline**
- August 15, 2023: **Internal Reviews Completed**
- August 20, 2023: **Author Notification**
- September 15, 2023: **Submission Camera Ready Deadline**

Given that submissions will not be archived (short position statements), we do not have publication constraints and will revise/extend these dates based on the number of submissions and requests from the community (we could accept submissions up to end of September if need be, with a camera ready deadline mid-October).

8 Intended Outcomes

The primary intended outcome of this workshop is to establish an initial list of challenges and opportunities and to identify a group of authors that will work together on a joint publication that lays out a research agenda of the topic.

9 Measure of Success and Mitigation Strategy

We will consider the call for participation to be successful if we receive at least 8 submissions. The cutoff for counting the number of submissions is August 31 (given that we are likely to extend the deadlines). If we do not count 8 submissions by the initial deadline of July 31st, we will extend the deadline to August 31st. If we do not count 8 submissions by August 31, we will withdraw the workshop.

10 Technology Needed

Although no particular technology is required, we would like to have access to a room that is well-suited to groupwork, i.e. with tables and chairs, rather than only chairs. We would also need flipcharts and pens.

11 Plan For Publication

The plan for submission is: *Short position statements / work in progress notes (similar to posters).*

12 Number of Poster Slots Requested

Given the visual nature of the requested submissions, we request up to 8 poster slots. If more than 8 submissions are accepted, the workshop organizers will invite selected submissions to prepare a poster for a maximum of 8. This selection will be made mostly based on the quality of the illustrations.

13 Organizer's Background, Related Publications and Research

Charles Perin, cperin@uvic.ca
(http://charlesperin.net/)
Charles Perin is an Associate Professor of Computer Science at the University of Victoria. His research focuses on designing and studying new interactions for visualizations and on understanding how people may make use of and interact with visualizations in their everyday lives, including mobile and physical visualization. He has co-organized six workshops at VIS (2015, 2017, 2020, 2021, 2022, 2023). Relevant to this workshop, he has published several papers on the topic of sports visualization in the past decade [34–37, 46] and is conducting research on beyond-desktop visualizations/physicalizations [2, 22] including mobile visualizations [6, 21].

Tica Lin, mlin@g.harvard.edu
(https://ticalin.com)
Tica Lin is a PhD candidate in the Visual Computing Group at Harvard University, advised by Hanspeter Pfister. Her research interests include immersive analytics, human-AI interaction, and SportsXR [25, 29]. Her work addresses challenges in presenting data in dynamic physical environments for situated analytics. Through collaboration with sports experts and colleagues, she has investigated the design of XR visualizations in the physical contexts for sports applications, including first-person visualizations for motor skill training [28] and spatial searching [8, 30] as well as interactive spatiotemporal data visualizations for live games [9, 26] and video analysis [25], among other real-world contexts [27]. Her research closely aligns with and underscores the aims of this workshop.

Lijie Yao, yaolijie0219@gmail.com
(https://lijieyao.com)
Lijie Yao is a research fellow at AVIZ, Inria. She completed her PhD thesis on "Situated Visualization in Motion" at AVIZ and Université Paris-Saclay, supervised by Petra Isenberg and Anastasia Bezerianos. Her work focuses on exploring the impact of motion factors on visualization perception and how to best design visualizations in motion. Collaborating with colleagues, she defined *visualization in motion* and demonstrated that simple visual representations could be read even under high speeds and irregular trajectories [54, 56] and explored how to embed and design *visualizations in motion* in real application scenarios, such as swimming [55, 57], video games [4, 5], and mobile and wearable use cases [18]. Besides, she contributes to situated visualizations using in outdoor environment [20].

Yalong Yang, yalong.yang@gatech.edu
(https://ivi.cc.gatech.edu/)
Yalong Yang is an Assistant Professor in the School of Interactive Computing at Georgia Tech. His research centers on the design and evaluation of visualizations, user interfaces, and interactions within virtual and augmented reality (VR/AR) environments. Yang has co-organized Immersive Analytics workshops, served as online experience chair for ISMAR 2023, and co-edited a special issue on Immersive Analytics. His interests encompass fundamental visualization and HCI challenges in VR/AR, as well as applied domains such as sports. In collaboration with colleagues, he has created innovative visualizations for geographic data in immersive environments [51–53], developed embodied interactions for data science within VR/AR [15, 16], explored collaborative visual analytics in VR/AR [44], and built sportsXR applications [8, 25, 26, 28, 29]. Additionally, he has conducted rigorous controlled studies to advance the understanding of immersive user experiences [14, 30, 41, 50].

Maxime Cordeil, m.cordeil@uq.edu.au
(https://eecs.uq.edu.au/profile/5945/maxime-cordeil)
Dr. Maxime Cordeil's research explores how Virtual and Augmented Reality technologies enable users to better understand and interact with complex data. He also focuses on the engineering

and evaluation of interactive visualisation systems and the design of Augmented Reality interfaces for industry applications. He has authored 60+ publications in top-ranked Human Computer Interaction and Information Visualisation conference proceedings and journals, including in ACM CHI, ACM UIST, ACM ISS, IEEE InfoVis/TVCG, and IEEE VR. Relevant to this workshop, he has extensive experience in immersive analytics [7, 10–12, 43] and visualization in augmented and mixed reality [1, 39, 42].

Wesley Willett, email@email.com
(`https://dataexperience.cpsc.ucalgary.ca`)
Dr. Wesley Willett is an Associate Professor at the University of Calgary where he heads the Data Experience Lab. His research focuses on interaction and visualization techniques that connect data to experiences in the physical world. He has also co-organized past workshops on Personal Visualization (2015) and Visualization Futures (2020) at IEEE VIS as well as workshops on Immersive Analytics at ACM CHI (2019, 2020). Related to the theme of this workshop, Dr. Willett has published foundational work on situated and embedded visualization [49] and the design of new empowering first-person visualization systems [48], as well as design approaches [40] and grand challenges for immersive analytics [12]. His work also examines the use of speculative and design futuring approaches for visualization and interaction design [19].

REFERENCES

[1] B. Bach, R. Sicat, J. Beyer, M. Cordeil, and H. Pfister. The hologram in my hand: How effective is interactive exploration of 3d visualizations in immersive tangible augmented reality? *IEEE Transactions on Visualization and Computer Graphics*, 24(1):457–467, 2018. doi: 10.1109/TVCG.2017.2745941

[2] F. Botros, C. Perin, B. A. Aseniero, and S. Carpendale. Go and grow: Mapping personal data to a living plant. In *Proceedings of the Working Conference on Advanced Visual Interfaces*, AVI '16. ACM, New York, NY, USA, 2016.

[3] N. Bressa, H. Korsgaard, A. Tabard, S. Houben, and J. Vermeulen. What's the situation with situated visualization? a survey and perspectives on situatedness. *IEEE Transactions on Visualization and Computer Graphics*, 28(1):107–117, 2021.

[4] F. Bucchieri, L. Yao, and P. Isenberg. Situated Visualization in Motion for Video Games. Posters of the European Conference on Visualization (EuroVis), June 2022. Poster. doi: 10.2312/evp.20221119

[5] F. Bucchieri, L. Yao, and P. Isenberg. Visualization in Motion in Video Games for Different Types of Data. In *Journée Visu 2022*. Bordeaux, France, June 2022.

[6] S. Carpendale, P. Isenberg, C. Perin, T. Blascheck, F. Daneshzand, A. Islam, K. Currier, P. Buk, V. Cheung, L. Quach, et al. Mobile visualization design: An ideation method to try, 2021.

[7] T. Chandler, M. Cordeil, T. Czauderna, T. Dwyer, J. Glowacki, C. Goncu, M. Klapperstueck, K. Klein, K. Marriott, F. Schreiber, et al. Immersive analytics. In *2015 Big Data Visual Analytics (BDVA)*, pp. 1–8. IEEE, 2015.

[8] Z. Chen, D. Chiappalupi, T. Lin, Y. Yang, J. Beyer, and H. Pfister. Rl-label: A deep reinforcement learning approach intended for ar label placement in dynamic scenarios. *IEEE transactions on visualization and computer graphics*, 2023.

[9] Z. Chen, Q. Yang, J. Shan, T. Lin, J. Beyer, H. Xia, and H. Pfister. iball: Augmenting basketball videos with gaze-moderated embedded visualizations. In *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems*, pp. 1–18, 2023.

[10] M. Cordeil, A. Cunningham, B. Bach, C. Hurter, B. H. Thomas, K. Marriott, and T. Dwyer. Iatk: An immersive analytics toolkit. In *2019 IEEE Conference on Virtual Reality and 3D User Interfaces (VR)*, pp. 200–209, 2019. doi: 10.1109/VR.2019.8797978

[11] M. Cordeil, A. Cunningham, T. Dwyer, B. H. Thomas, and K. Marriott. Imaxes: Immersive axes as embodied affordances for interactive multivariate data visualisation. In *Proceedings of the 30th Annual ACM Symposium on User Interface Software and Technology*, UIST '17, p. 71–83. Association for Computing Machinery, New York, NY, USA, 2017. doi: 10.1145/3126594.3126613

[12] B. Ens, B. Bach, M. Cordeil, U. Engelke, M. Serrano, W. Willett, A. Prouzeau, C. Anthes, W. Büschel, C. Dunne, et al. Grand challenges in immersive analytics. In *2021 CHI Conference on Human Factors in Computing Systems*, 2021.

[13] Y. Fu and J. Stasko. Hoopinsight: Analyzing and comparing basketball shooting performance through visualization. *IEEE Transactions on Visualization and Computer Graphics*, 30(1):858–868, 2024. doi: 10.1109/TVCG.2023.3326910

[14] H. H. Huang, H. Pfister, and Y. Yang. Is embodied interaction beneficial? a study on navigating network visualizations. *Information Visualization*, 2023.

[15] S. In, E. Krokos, K. Whitley, C. North, and Y. Yang. Evaluating navigation and comparison performance of computational notebooks on desktop and in virtual reality. In *2024 CHI Conference on Human Factors in Computing Systems*, 2024.

[16] S. In, T. Lin, C. North, H. Pfister, and Y. Yang. This is the table i want! interactive data transformation on desktop and in virtual reality. *IEEE Transactions on Visualization and Computer Graphics*, 2023.

[17] P. Isenberg, F. Heimerl, S. Koch, T. Isenberg, P. Xu, C. Stolper, M. Sedlmair, J. Chen, T. Möller, and J. Stasko. vispubdata.org: A metadata collection about IEEE visualization (VIS) publications. *IEEE Transactions on Visualization and Computer Graphics*, 23(9):2199–2206, Sept. 2017. doi: 10.1109/TVCG.2016.2615308

[18] A. Islam, L. Yao, A. Bezerianos, T. Blascheck, T. He, B. Lee, R. Vuillemot, and P. Isenberg. Reflections on visualization in motion for fitness trackers. In *MobileHCI 2022-24th International Conference on Mobile Human-Computer Interaction*, 2022.

[19] A. Ivanov, T. Au Yeung, K. Blair, K. Danyluk, G. Freeman, M. Friedel, C. Hull, M. Y.-S. Hung, S. Pratte, and W. Willett. One week in the future: Previs design futuring for hci research. In *Proceedings of the 2022 CHI Conference on Human Factors in Computing Systems*, pp. 1–15, 2022.

[20] Y. Jansen, F. Bucchieri, P. Dragicevic, M. Hachet, M. Koval, L. Petiot, A. Prouzeau, D. Schmalstieg, L. Yao, and P. Isenberg. Envisioning Situated Visualizations of Environmental Footprints in an Urban Environment. In *VIS4Good - Visualization for Social Good workshop held as part of IEEE VIS 2022*. Oklahoma City, United States, Oct. 2022. doi: 10.5281/zenodo.7053934

[21] R. Langner, L. Besançon, C. Collins, T. Dwyer, P. Isenberg, T. Isenberg, B. Lee, C. Perin, and C. Tominski. An introduction to mobile data visualization. In *Mobile Data Visualization*, pp. 1–32. Chapman and Hall/CRC, 2021.

[22] M. Le Goc, C. Perin, S. Follmer, J.-D. Fekete, and P. Dragicevic. Dynamic composite data physicalization using wheeled microrobots. *IEEE Transactions on Visualization and Computer Graphics*, 25(1):737–747, Jan 2019. doi: 10.1109/TVCG.2018.2865159

[23] B. Lee, M. Brehmer, P. Isenberg, E. K. Choe, R. Langner, and R. Dachselt. Data visualization on mobile devices. In *Extended Abstracts of the 2018 CHI Conference on Human Factors in Computing Systems*, CHI EA '18, p. 1–8. Association for Computing Machinery, New York, NY, USA, 2018. doi: 10.1145/3170427.3170631

[24] B. Lee, R. Dachselt, P. Isenberg, and E. K. Choe. *Mobile Data Visualization*. CRC Press, 2021.

[25] T. Lin, Z. Chen, J. Beyer, Y. Wu, H. Pfister, and Y. Yang. The ball is in our court: Conducting visualization research with sports experts. *IEEE Computer Graphics and Applications*, 43(1):84–90, 2023.

[26] T. Lin, Z. Chen, Y. Yang, D. Chiappalupi, J. Beyer, and H. Pfister. The quest for omnioculars: Embedded visualization for augmenting basketball game viewing experiences. *IEEE transactions on visualization and computer graphics*, 29(1):962–971, 2022.

[27] T. Lin, B. Lafreniere, Y. Xu, T. Grossman, D. Wigdor, and M. Glueck. Xr input error mediation for hand-based input: Task and context influences a user's preference. In *2023 IEEE International Symposium on Mixed and Augmented Reality (ISMAR)*, pp. 1006–1015. IEEE, 2023.

[28] T. Lin, R. Singh, Y. Yang, C. Nobre, J. Beyer, M. A. Smith, and H. Pfister. Towards an understanding of situated ar visualization for basketball free-throw training. In *2021 CHI Conference on Human Factors in Computing Systems*, pp. 1–13, 2021.

[29] T. Lin, Y. Yang, J. Beyer, and H. Pfister. Sportsxr–immersive analytics in sports. *arXiv preprint arXiv:2004.08010*, 2020.

[30] T. Lin, Y. Yang, J. Beyer, and H. Pfister. Labeling out-of-view objects in immersive analytics to support situated visual searching. *IEEE Transactions on Visualization and Computer Graphics*, 2021.

[31] K. Marriott, F. Schreiber, T. Dwyer, K. Klein, N. H. Riche, T. Itoh, W. Stuerzlinger, and B. H. Thomas. *Immersive analytics*, vol. 11190. Springer, 2018.

[32] E. Mencarini, A. Rapp, A. Colley, F. Daiber, M. D. Jones, F. Kosmalla, S. Lukosch, J. Niess, E. Niforatos, P. W. Woźniak, and M. Zancanaro. New trends in hci and sports. In *Adjunct Publication of the 24th International Conference on Human-Computer Interaction with Mobile Devices and Services*, MobileHCI '22. Association for Computing Machinery, New York, NY, USA, 2022. doi: 10.1145/3528575.3551426

[33] S. Nylander, J. Tholander, F. Mueller, and J. Marshall. Hci and sports. In *CHI '14 Extended Abstracts on Human Factors in Computing Systems*, CHI EA '14, p. 115–118. Association for Computing Machinery, New York, NY, USA, 2014. doi: 10.1145/2559206.2559223

[34] C. Perin, J. Boy, and F. Vernier. Using Gap Charts to Visualize the Temporal Evolution of Ranks and Scores. *Computer Graphics & Applications*, 2016.

[35] C. Perin, R. Vuillemot, and J.-D. Fekete. Soccerstories: A kick-off for visual soccer analysis. *IEEE Transactions on Visualization and Computer Graphics*, 19(12):2506–2515, 2013. doi: 10.1109/TVCG.2013.192

[36] C. Perin, R. Vuillemot, and J.-D. Fekete. À Table!: Improving Temporal Navigation in Soccer Ranking Tables. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, CHI '14, pp. 887–896. ACM, Toronto, Canada, 2014. doi: 10.1145/2556288.2557379

[37] C. Perin, R. Vuillemot, C. D. Stolper, J. T. Stasko, J. Wood, and S. Carpendale. State of the art of sports data visualization. *Computer Graphics Forum*, 37(3):663–686, 2018. doi: 10.1111/cgf.13447

[38] H. Pileggi, C. D. Stolper, J. M. Boyle, and J. T. Stasko. Snapshot: Visualization to propel ice hockey analytics. *IEEE Transactions on Visualization and Computer Graphics*, 18(12):2819–2828, 2012.

[39] V. Pooryousef, M. Cordeil, L. Besançon, C. Hurter, T. Dwyer, and R. Bassed. Working with forensic practitioners to understand the opportunities and challenges for mixed-reality digital autopsy. In *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems*, CHI '23. Association for Computing Machinery, New York, NY, USA, 2023. doi: 10.1145/3544548.3580768

[40] A. Prouzeau, Y. Wang, B. Ens, W. Willett, and T. Dwyer. Corsican twin: Authoring in situ augmented reality visualisations in virtual reality. In *Proceedings of the international conference on advanced visual interfaces*, pp. 1–9, 2020.

[41] G. Reiske, S. In, and Y. Yang. Multi-focus querying of the human genome information on desktop and in virtual reality: an evaluation. In *2023 IEEE International Symposium on Mixed and Augmented Reality (ISMAR)*, pp. 1123–1131. IEEE, 2023.

[42] K. A. Satriadi, J. Smiley, B. Ens, M. Cordeil, T. Czauderna, B. Lee, Y. Yang, T. Dwyer, and B. Jenny. Tangible globes for data visualisation in augmented reality. In *Proceedings of the 2022 CHI Conference on Human Factors in Computing Systems*, CHI '22. Association for Computing Machinery, New York, NY, USA, 2022. doi: 10.1145/3491102.3517715

[43] R. Sicat, J. Li, J. Choi, M. Cordeil, W.-K. Jeong, B. Bach, and H. Pfister. Dxr: A toolkit for building immersive data visualizations. *IEEE Transactions on Visualization and Computer Graphics*, 25(1):715–725, 2019. doi: 10.1109/TVCG.2018.2865152

[44] W. Tong, M. Xia, K. K. Wong, D. A. Bowman, T.-C. Pong, H. Qu, and Y. Yang. Towards an understanding of distributed asymmetric collaborative visualization on problem-solving. In *2023 IEEE Conference Virtual Reality and 3D User Interfaces (VR)*, pp. 387–397. IEEE, 2023.

[45] V. van Rheden, T. Grah, A. Meschtscherjakov, R. Patibanda, W. Liu, F. Daiber, E. van den Hoven, and F. F. Mueller. Out of your mind!? embodied interaction in sports. In *Extended Abstracts of the 2021 CHI Conference on Human Factors in Computing Systems*, CHI EA '21. Association for Computing Machinery, New York, NY, USA, 2021. doi: 10.1145/3411763.3441329

[46] R. Vuillemot and C. Perin. Sports Tournament Predictions Using Direct Manipulation. *Computer Graphics & Applications*, 2016.

[47] J. Wang, K. Zhao, D. Deng, A. Cao, X. Xie, Z. Zhou, H. Zhang, and Y. Wu. Tac-simur: Tactic-based simulative visual analytics of table tennis. *IEEE Transactions on Visualization and Computer Graphics*, 26(1):407–417, 2020. doi: 10.1109/TVCG.2019.2934630

[48] W. Willett, B. A. Aseniero, S. Carpendale, P. Dragicevic, Y. Jansen, L. Oehlberg, and P. Isenberg. Perception! immersion! empowerment! superpowers as inspiration for visualization. *IEEE transactions on visualization and computer graphics*, 28(1):22–32, 2021.

[49] W. Willett, Y. Jansen, and P. Dragicevic. Embedded data representations. *IEEE transactions on visualization and computer graphics*, 23(1):461–470, 2016.

[50] Y. Yang, M. Cordeil, J. Beyer, T. Dwyer, K. Marriott, and H. Pfister. Embodied navigation in immersive abstract data visualization: Is overview+ detail or zooming better for 3d scatterplots? *IEEE Transactions on Visualization and Computer Graphics*, 27(2):1214–1224, 2020.

[51] Y. Yang, T. Dwyer, B. Jenny, K. Marriott, M. Cordeil, and H. Chen. Origin-destination flow maps in immersive environments. *IEEE transactions on visualization and computer graphics*, 25(1):693–703, 2018.

[52] Y. Yang, T. Dwyer, K. Marriott, B. Jenny, and S. Goodwin. Tilt map: Interactive transitions between choropleth map, prism map and bar chart in immersive environments. *IEEE Transactions on Visualization and Computer Graphics*, 27(12):4507–4519, 2020.

[53] Y. Yang, B. Jenny, T. Dwyer, K. Marriott, H. Chen, and M. Cordeil. Maps and globes in virtual reality. In *Computer Graphics Forum*, vol. 37, pp. 427–438. Wiley Online Library, 2018.

[54] L. Yao, A. Bezerianos, and P. Isenberg. Situated Visualization in Motion. Posters of the IEEE Conference on Visualization, Oct. 2020. Poster.

[55] L. Yao, A. Bezerianos, R. Vuillemot, and P. Isenberg. Situated Visualization in Motion for Swimming. In *Journée Visu 2022*. Bordeaux, France, June 2022.

[56] L. Yao, A. Bezerianos, R. Vuillemot, and P. Isenberg. Visualization in motion: A research agenda and two evaluations. *IEEE Transactions on Visualization and Computer Graphics*, 2022.

[57] L. Yao, R. Vuillemot, A. Bezerianos, and P. Isenberg. Designing for visualization in motion: Embedding visualizations in swimming videos. *IEEE Transactions on Visualization and Computer Graphics*, 30(3):1821–1836, 2024. doi: 10.1109/TVCG.2023.3341990