ERCIM fellowship Programme
Final scientific report

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Host Organisation	CWI

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I – SCIENTIFIC ACTIVITY DURING YOUR FELLOWSHIP

During my fellowship, my focus was on enabling large-scale immersive communications that provide high-quality experience without saturating the network resources. Specifically, I aimed to further investigate navigation trajectories in 6-DoF Extended Reality (XR) experiences to detect key users' behaviours and develop new tools for this immersive application. To achieve this, I began my fellowship by examining how the user experience in Virtual Reality (VR) with 6-Degrees-of-Freedom (DoF) is affected by both visual content quality and user disposition. I based my analysis on traditional statistical metrics, existing 6-DoF techniques, and adapted tools to analyse user behaviour in immersive spaces with 3-DoF. The research highlighted the importance of user disposition in interacting with immersive content and suggested that user can be profiled, which can also provide valuable information for future applications, such as live streaming services and user-based quality assessment methods. This first study resulted in a conference paper [1] published in a workshop on Interactive eXtended Reality, collocated with ACM Multimedia (ACM MM) 2022, which is one of the main conferences in my research area. However, this work has also highlighted the limitations of current behavioural metric and thus, the lack of a robust and holistic metric capable to capture user behaviour in its globally, making behavioural analysis not straightforward. From here, the need of developing new metrics and methodologies to be able to properly analyse user behaviour in 6-DoF VR environment. Thus, in the following I focused on extending existing behavioural methodologies to better model user behaviours in in 6 Degree-of-Freedom (DoF) environments, which is more complex than their 3-DoF counterparts. I proposed new metrics that consider both user position and viewing direction; these metrics has been validated and tested on real user navigation paths in 6-DoF VR conditions. Our investigations showed that these metrics perform better in detecting user similarity, which is essential for building user-centric systems. This work resulted in a conference paper [2] that will be presented next June in the main track of ACM Multimedia System (ACM MMSys), which is the other main conference in my research field. In the final part of my fellowship, I started to explore how my behavioural study can be exploited in algorithms that can effectively predict user navigation in immersive environments. In detail, currently I am testing different deep learning network (i.e., LSTM, RNN) to examine any correlation between the accuracy of prediction and the type of user navigation (e.g., more eclectic users vs more static ones). The current study is not completed yet but eventually it will result in a future publication. To conclude, my research during the ERCIM fellowship has contributed to the overall open problem of behavioural analysis in 6-DoF XR systems by investigating and proposing new behavioural tools and methodologies specifically built for this immersive environment. This research has the potential to enable new modalities for trajectory prediction, live streaming services optimized for users' profiles, and user-based quality-of-experience assessment methods.

Beyond to my scientific research, I have been actively involved in the multimedia scientific community from different perspectives. I took part of TPC for different conferences and workshop, such as ACM MMsys, ACM MM, QoMEx, MMVE and IXR. I have been involved also in disseminating scientific information on social media for the multimedia community as Information Director for ACM Special Interest Group on Multimedia (SIGMM, http://sigmm.org) Records (https://records.sigmm.org). Finally last March 2022, I was one of the organisers of a spring school on Social XR (https://www.dis.cwi.nl/spring-school) that was held at CWI. The aim of the school was to give an overview about Social XR, as a new medium for communication and collaboration

following an interdisciplinary approach. We welcomed more than 30 PhD students from different backgrounds (i.e., technology, social sciences, and humanities). The program included a total of 14 lectures and mini-tutorials on different areas of research related to Social XR private to the students but also 4 open public keynotes.

II – PUBLICATION(S) DURING YOUR FELLOWSHIP

Published:

[1] Silvia Rossi, Irene Viola, and Pablo Cesar. 2022. "Behavioural Analysis in a 6-DoF VR System: Influence of Content, Quality and User Disposition". In Proceedings of the 1st Workshop on Interactive eXtended Reality (IXR '22). Association for Computing Machinery, New York, NY, USA. https://doi.org/10.1145/3552483.3556454

Abstract:

This work presents an explorative behavioural analysis of users navigating in an immersive space aimed at enabling the next-generation multimedia systems. Our main goal is to understand how the user experience of immersive content with 6-Degrees-of-Freedom (DoF) is affected not only by the visual content and its quality but also by the disposition of the user. We based our investigations on traditional statistical metrics, on techniques that have been already used for 6-DoF, as well as adapted 3-DoF tools to be used in this new context. We show the limitation of each metric in giving a complete interpretation of user behaviour, and we draw insights on important factors to be considered when analysing and predicting navigation trajectories. Specifically, we have noticed in our behavioural investigations that the user disposition plays an important role in the way of interacting with the immersive content. This opens the gate to user profiles (i.e., a collection of key information that describes the behavioural features of a single or group of users) that would be beneficial for different purposes in future immersive applications such as enabling new modalities for live streaming services optimised per user profiles but also for user-based quality assessment methods.

Accepted and to be published:

[2] Silvia Rossi, Irene Viola, Laura Toni, and Pablo Cesar. 2023. "Extending 3-DoF metrics to model user behaviour similarity in 6-DoF immersive applications". In Proceedings of the 14th ACM Multimedia Systems Conference (MMSys '23), June 7–10, 2023, Vancouver, BC, Canada. ACM, New York, NY, USA, 12 pages. https://doi.org/10.1145/3587819.3590976

Abstract:

Immersive reality technologies, such as Virtual and Augmented Reality, have ushered a new era of user-centric systems, in which every aspect of the coding–delivery–rendering chain is tailored to the interaction of the users. Understanding the actual interactivity and behaviour of the users is still an open challenge and a key step to enabling such a user-centric system. Our main goal is to extend the applicability of existing behavioural methodologies for studying user navigation in the case of 6 Degree-of-Freedom (DoF). Specifically, we first compare the navigation in 6-DoF with its 3-DoF counterpart highlighting the main differences and novelties. Then, we define new metrics aimed at better modelling behavioural similarities between users in a 6-DoF system. We validate and test our solutions on real navigation paths of users interacting with dynamic volumetric media in 6-DoF Virtual Reality conditions. Our results show that metrics that consider both user position and viewing direction better perform in detecting user similarity while navigating in a 6-DoF system. Having easy-to-use but robust metrics that underpin multiple tools and answer the question "how do we detect if two users look at the same content?" open the gate to new solutions for a user-centric system.

III – ATTENDED SEMINARS, WORKHOPS, CONFERENCES

- ACM Multimedia System Conference 2022 (ACM MMSys '22), June 14-17, 2022 Athlone, Ireland - https://mmsys2022.ie
- ACM Multimedia 2022 (ACM MM '22), October 10-14, 2022, Lisbon, Portugal - https://2022.acmmm.org
- VQEG Meeting (Online), December 12-16, 2022 - https://www.vqeg.org/meetings-home/
- ICT.Open, April 19-20, 2023 - https://www.ictopen.nl

IV – RESEARCH EXCHANGE PROGRAMME (REP)

As part of the research exchange programme, I had the opportunity to visit **Dr Katrien De Moor** at her department of Information Security and Communication Technology in **NTNU**, Norway, in **March 20-24, 2023**. I found this visit to be a valuable experience and in line with my research. Spending few days with Katrin, who is a former ERCIM fellow, was inspiring as I was able to learn more about her research, and observe how projects and collaborations are managed in her department. We also discussed her research journey after her ERCIM fellowship. This was beneficial and helpful not only for my research but also for my personal growth as a woman in research: having contact with senior and successful female figures is always inspiring and supportive. Katrien has also introduced me to her students, postdocs and colleagues at the institute, providing me with an opportunity to expand my connection and learn more about various research topic. In addition, I gave a presentation about my research that was well-received by a diverse audience, including people from networking, security, and cryptography backgrounds, which led to interesting and stimulating discussions.