Mixed Reality-Based Platform for Remote Support and Diagnosis in Primary Care: A Position Paper

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Keywords: Mixed Reality, 5G Communication, Telemedicine, Primary Care, Remote Assistance, Medical Training, Rural Healthcare.

Abstract: This position paper proposes the design of MRP-5G, a mixed reality-based platform for remote support and diagnosis in primary care by integrating 5G communication technologies and Artificial Intelligence. MRP-5G will facilitate real-time communication between primary care staff and medical specialists, providing functionalities such as real-time videoconferencing, virtual annotation, and intelligent session indexing for medical training purposes. The proposed architecture is modular and scalable. It includes functional layers for networked communication, integration of LLM-based chatbots, and secure data management. Our approach aims to provide low latency, high quality interactions, and integration of augmented 3D information into clinical workflows. MRP-5G will positively impact on remote healthcare by improving clinical decision-making, enhancing medical education and addressing inequalities in access to healthcare in rural regions. In the next few years, we intend to address key healthcare challenges such as limited access to specialists in rural areas and the need for technological solutions that enable efficient, interactive, and equitable care. Our work, currently in the design and implementation phase of first functional prototypes, aims to stimulate critical discussion and collaboration in the scientific community to refine and scale this innovative approach.

1 CONTEXT AND PROPOSAL JUSTIFICATION

The integration of innovative technologies into healthcare systems is essential to improve the effectiveness and efficiency of patient diagnosis, particularly in primary care. General practitioners (GPs) are at the forefront of diagnosing patients on a daily basis, whether in clinics, during home visits, or in unexpected medical emergencies. In such scenarios, the presence of a specialist to confirm diagnoses or provide technical support is invaluable. However, the feasibility of ensuring the availability of specialists across different medical disciplines, locations, and timeframes is an ongoing challenge, particularly in rural areas experiencing depopulation. This issue reinforces the need for technological solutions that enable specialists to provide real-time remote support to GPs from their workplace. Similarly, nurses could benefit from similar support structures to ensure access to expertise regardless of location.

To address this unmet clinical need, tele-health solutions must provide an optimal user experience for both the GP treating the patient and the specialist providing remote support. For the former, the technology should integrate seamlessly into their workflow and be as unobtrusive as possible. Mixed reality (MR) technologies, such as head-mounted displays, allow doctors to interact with augmented 3D virtual information while maintaining their focus on the physical patient. For the latter, specialists should have real-time visual and contextual insight into the GP's environment, enabling precise guidance through annotations or virtual overlays visible to the GP in the field. Effective implementation requires bi-directional, low-latency communication to facilitate informed and rapid decision making, which is criti-

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García, F. M., Essalhi, M., Espejo, S., Sánchez-Sobrino, S., Albusac, J. A. and Vallejo, D.
Mixed Reality-Based Platform for Remote Support and Diagnosis in Primary Care: A Position Paper.
DOI: 10.5220/0013352100003929

In *Proceedings of the 27th International Conference on Enterprise Information Systems (ICEIS 2025) - Volume 2*, pages 565-572
ISBN: 978-989-758-749-8; ISSN: 2184-4992

cal in time-sensitive medical situations. In addition, recording and indexing such interactions for future medical training purposes adds value by building a knowledge repository.

On the other hand, the advent of 5G networks offers a unique opportunity to revolutionise these interactions. With its low latency, high bandwidth and reliable connectivity, 5G technology ensures smooth, real-time transmission of high-definition audio and video between healthcare providers. These features are particularly important in scenarios where instant communication between GPs and specialists can directly impact patient outcomes.

This issue is even more critical in rural areas, where healthcare disparities are exacerbated by depopulation and ageing populations. Innovative technologies can play a key role in addressing these challenges, driving the digitalisation of healthcare and making remote services accessible to rural communities. Such approaches are also in line with broader socio-economic strategies aimed at revitalising depopulated areas. Castilla-La Mancha (the Spanish region where our university is located), one of the European locations most affected by depopulation, illustrates the urgency of this issue. More than 76% of its municipalities have a population density of less than 12.5 inhabitants per km^2, a threshold considered by the European Union to be at risk of depopulation. In addition, 58% of its municipalities are at serious risk of depopulation. These challenges have led to the adoption of Law 2/2011 on economic, social and fiscal measures to combat depopulation and develop the rural environment.

Rural healthcare costs are disproportionately high for face-to-face specialised services, making access to quality care even more difficult. Technology-based solutions for telemedicine offer a cost-effective and scalable alternative to bridge this gap, ensuring equitable access to care regardless of geographical constraints. This proposal is in line with national and regional strategies, including Spain's National Strategy to Address the Demographic Challenge and Castilla-La Mancha's Research and Innovation Strategy for Smart Specialisation (RIS-3). By fostering innovation, improving access to public services and promoting territorial cohesion, these strategies provide a basis for addressing health inequalities while supporting sustainable regional development. This proposal exploits the synergies between these initiatives to promote long-term, inclusive growth and resilience.

2 GOAL AND HYPOTHESIS

The aim of this research work is therefore to create MRP-5G, a technological platform designed for primary care medical staff, in particular GPs, but also nurses, in terms of remote diagnosis and support from specialists. Our research hypothesis is that it is possible to increase and scale the functional capabilities of primary care through an innovative solution based on MR and 5G communication infrastructures. To this end, primary care staff will wear MR glasses that display an application capable of establishing real-time, high-quality videoconferencing sessions with the specialist over a 5G infrastructure (see Figure 1). The specialist, in turn, will use a desktop application to interact and generate information and guidance that the primary care provider will view through the MR glasses. This remote care approach, which can be used from primary care centres as well as the patient's home where 5G coverage is available, has significant implications for rural areas. The 3 main contributions of the proposal that we identify are: 1) a transversal and integrative nature, characterised not only by real-time communication between doctors, but also by its practical application; three specific use cases are envisaged: (i) use in primary care centres, (ii) use at the patient's home, and (iii) use in medical emergencies; 2) MRP-5G will serve as a starting point for addressing other unresolved clinical challenges where real-time remote care, supported by a MR interaction paradigm over a 5G infrastructure, adds value to a traditional care approach; 3) MRP-5G will be able to offer a training-focused approach derived from the intelligent recording and indexing of support and diagnostic sessions between GPs and specialists.

2.1 Objectives

The overall objective of this research work is the creation of MRP-5G, a technological platform for primary care aimed at remote medical diagnosis and treatment. Particularly, the platform will be capable of recreating the assistance that primary care personnel would receive remotely from a specialist physician, as if the latter were physically beside the former while attending to a patient. To achieve this, the primary care personnel will wear MR glasses, on which an application capable of establishing high-quality, real-time video conference sessions over a 5G infrastructure with the specialist physician will be displayed. The specialist, in turn, will use a desktop application to interact and generate information and guidance that the primary care personnel will view on the MR glasses. This remote care approach, which

Figure 1: Abstract representation of one of the use cases related to the proposal discussed in this research article. On the left, the specialist provides remote support from their workstation. On the right, the GP diagnoses a patient using MR glasses that enable interaction with the real world and communication with the specialist.

can be used both from primary care centres and from the patient's own home, provided there is 5G coverage, has a significant impact in rural environments.

This general objective is divided into the following sub-objectives:

- Ensure smooth, low-latency communication and user experience for real-time high-definition audio/video transmission, with secure and encrypted communications.
- Develop a MR application for integrating 3D virtual information and patient monitoring into the care environment.
- Create a desktop application for specialists to interact and view the primary care staff's perspective through MR glasses.
- Record, store, and smartly index video conferences for evidence, training, and reference in similar medical cases.
- Use open standards and libraries to facilitate technology transfer and reduce hardware dependencies.
- Validate the solution in a laboratory environment and conduct initial acceptance tests with healthcare centres.

2.2 Contributions

MRP-5G integrates emerging technologies such as MR and 5G communication networks, which would allow more fluid and effective collaboration between medical professionals, ultimately leading to greater efficiency and effectiveness in healthcare. We believe that the results obtained after completing the development of MRP-5G will represent a significant scientific and technical advancement in the field of telemedicine. Specifically, we identify the following contributions:

- The cross-cutting and integrative nature of MRP-5G, not only in terms of real-time interaction and communication between medical staff, but also in terms of practical application. In this sense, we envision three specific use cases: i) use from a primary care center, ii) use from the patient's home, and iii) use in a medical emergency.
- Establishment of a starting point for other unresolved clinical challenges where real-time remote care, supported by a MR interaction paradigm over a 5G infrastructure, provides added value over a more traditional care approach.
- Capability to provide a training-focused approach derived from the intelligent recording and indexing of support and diagnostic sessions carried out between primary care physicians and specialist physicians.

3 RELATED WORK

3.1 Literature Review

As an emerging technology, MR has great potential in the area of telemedicine (Worlikar et al., 2023). The usefulness of telemedicine is highlighted in environments where trained physicians cannot access or are not present, such as on a commercial flight, on a battlefield, or in the home environment. Extended reality systems can be of interest in this context by providing useful information to the user with or without the direct intervention of professionals remotely (usually by videoconference) (Dinh et al., 2023), by relaying images and audio to guide highly skilled procedures, such as a specific diagnosis or the performance of surgical or emergency interventions such as the transfer of a critical patient by ambulance (Munzer et al., 2019).

Lu et al. recently published a paper detailing their experience of utilizing MR in the orthopedic surgical workflow across different scenarios such as preoperative planning, intraoperative guidance, surgical navigation, and telesurgery consultation (Lu et al., 2022). The study makes use of Hololens 2 and describes in detail the different modules comprising the system, including Data Collection and 3D Reconstruction, Cloud-Based 3D Model Storage and Rendering, and MR Holographic Imaging.

A related work proposes an AR-based system to remotely assist healthcare workers in taking biopsies (Samantaray et al., 2023), using the Microsoft Hololens 2 headset. The system projects a 3D model of the cervix into the real environment, allowing remote annotation by specialists. Although the solution has been tested in simulated environments with good results, there is great potential for its application in the remote diagnosis of cervical cancer.

Another noteworthy study involving the application of MR in medical interventions is that of Mitani et al (Mitani et al., 2021). This study represents the first reported use of this technology in the field of otolaryngology, specifically for tumor resection. HoloLens 2 devices were utilized for each physician, allowing for the sharing and visualization of the same holograms, alongside an associated system for the generation of specific 3D holograms to aid in preoperative planning and during the intervention. A related work was presented by Ivanov and colleagues (Ivanov et al., 2021), which reported another instance of the HoloLens 2 device being utilized for surgical interventions and preoperative planning, specifically for median neck and branchial cyst excision.

Moving on to telemedicine systems based on videoconferencing, the study published by Wang et al. can be found (Wang et al., 2017), which presents a HoloLens 1-based system that allows making a videoconference and the remote intervention of the medical expert through a 3D model of a hand that mimics the doctor's gestures. In 2016, Dickey et al. published a paper presenting a system for remote guidance of video-conferencing procedures using MR (Dickey et al., 2016). The system allowed team planning of the procedure and during which an expert physician assisted the headset user via videoconference. Another work by Andersen et al. (Andersen et al., 2016) shows a system (STAR, System for Telementoring with Augmented Reality) that allows a mentor to remotely position annotations in the field of vision of doctors to direct them during surgery, resulting in improved concentration and other variables. This is done using a tablet that acts as an AR device. The work of Davis and colleagues (Davis et al., 2016) is another example of a project in which AR is applied to telemedicine. In this case, the problem of telesurgery and its high costs compared to telepresence, i.e. the intervention of a doctor remotely via videoconferencing, is raised. Last year, Zhang et al. presented a study on the application of MR in telemedicine for remote collaboration in neuroendoscopic procedures. The system consists of a local video processing station, a MR HMD (Hololens 2), and a remote mobile device connected through 4G or 5G (Zhang et al., 2023). Another study related to remote assistance and tele-mentoring using MR is discussed by Tadlock et al. in 2022 (Tadlock et al., 2022), which explores the impact of this technology on combat casualty care-related procedures. The authors introduce a system composed of different devices, including HoloLens 2, HYC Vive Pro VR, and additional cameras to record the environments of novice participants and mentors.

Another recent paper presents Health-MR (Yin et al., 2024), a wearable MR system designed to support medical staff in patient monitoring. Health-MR integrates three main functions: facial recognition for patient identification, access to medical information from a cloud-based database, and non-invasive heart rate monitoring using image processing and Fast Fourier Transform (FFT). The results show that the system streamlines the retrieval of patient information and enables accurate, real-time monitoring.

Regarding network infrastructure for real-time communication in telemedicine, a relevant tool is represented by WebRTC, an API that allows P2P communication of audio, image, and binary data in real-time[1]. WebRTC offers low latency and is compatible with the most recent web browsers, making it ideal for videoconferencing. However, there is not much work using WebRTC in real applications for telemedicine services. In a previously reviewed publication by Wang et al. (Wang et al., 2017), it is noted that in general, when adopting WebRTC, the design and implementation details are very abstract and it is difficult to know which WebRTC components are being used. In the same work, they tried to use WebRTC but failed to integrate it with the game engine Unity. Another publication by Jang-Jaccard et al. (Jang-Jaccard et al., 2016) describes a case study of the development of a videoconferencing system for use in a real telemedicine application based on WebRTC, enabling

[1] https://webrtc.org

communication between healthcare staff and patients. This is a very comprehensive study, being one of the first and few works that expose in detail the architecture and implementation of such a system.

In 2017, Antón et al. published a paper presenting a system called KinectRTC, based on Microsoft Kinect and WebRTC for the purpose of telerehabilitation of patients through videoconferencing and multimodal data streaming (Antón et al., 2017). It was noted that in unfavorable scenarios (e.g. long-distance network), high latencies and packet losses were noted. An interesting work in this regard is the aforementioned study by Wang et al. (Wang et al., 2017), that presents a system that uses a HoloLens 1 device which allows establishing a video conference and remote guidance through a 3D hand model. In said work, an appendix is provided in which the problems encountered when implementing a videoconferencing system in HoloLens are reported, as well as the different options that were evaluated. They used the DASH protocol (Dynamic Streaming Over HTTP) to reduce latency. Another work that uses the DASH protocol is the one published by Kumar et al., in which a telemedicine system that uses a 5G network is presented (Kumar et al., 2023). In relation to the topics addressed in this proposal, it is worth noting some concluding remarks regarding the direct application and usefulness of 5G technology in healthcare, which are summarized by Dananjayan et al. (Dananjayan et al., 2021).

3.2 Health-5G Project: A MR-Based System for Remote Medical Assistance in Emergency Situations

One of the existing research works that is most directly related to the present research proposal is the project *AR for real-time support of mobile emergency units* (García et al., 2023)[2] (see Figure 2), developed by the Artificial Intelligence and Representation research group of the University of Castilla-La Mancha (Spain). This project was framed within the call for Pilot Projects of 5G Technology (Ref. 2019/C012/00075972) and funded by the Spanish Ministry of Economic Affairs and Digital Transformation from 01/09/2020 to 31/01/2023. This project was associated with situations where personnel in a medical emergency unit require real-time support from specialist doctors, materialized through the use of AR and the adoption of a fog computing-based paradigm, all supported by 5G infrastructure. In this work, we designed a distributed architecture consisting of four interconnected applications, each responsible for a key aspect: advanced human-computer interaction, highly efficient real-time videoconferencing, medical device integration, and communication infrastructure management. The AR layer was implemented through the Microsoft Hololens 2 ™ headset.

[2]https://youtu.be/3E0P4jHm1y0

Figure 2: Screenshot of the augmented reality system for real-time support of mobile emergency units (García et al., 2023).

4 OUR PROPOSAL

4.1 Architecture

The architecture presented in Figure 3 gives an overview of the functionality provided by the proposal discussed in this research paper. On the one hand, two roles can be clearly identified: i) the GP, labelled as *remote user*, and ii) the *specialist physician*, who will provide remote support from another location (typically a hospital). The platform uses a cloud-based infrastructure to facilitate its use in a transparent way for the medical staff involved, thus aiming for the smoothest possible interactive experience.

On the *remote user* side, a MR device, such as the Oculus Quest 3 glasses, will be used, with integrated functionality to conduct videoconferences, subject to user authentication, and to interact with an intelligent chatbot that can provide assistance when needed in retrieving technical information. The idea is that this chatbot will use advanced natural language processing models to answer questions and provide interactive support. The user experience will be realised through the implementation of hand tracking and MR, allowing for a natural and immersive interaction. On the other hand, the specialist accesses the system through a web browser to connect to the GP via videoconferencing, enabling the recording of sessions and, if necessary, accessing the interactive support of the chatbot integrated into the platform. The specialist interacts using standard equipment such as a webcam and microphone, ensuring real-time partic-

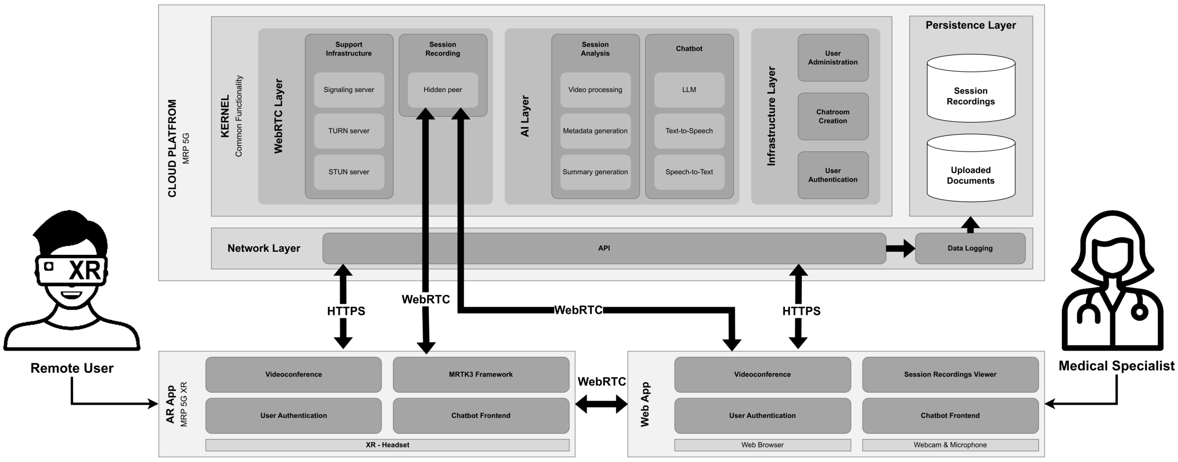

Figure 3: Overview of the proposed architecture, distinguishing the roles of the remote user (GP) and the specialist. The functionality offered by the platform is divided into 5 layers: network layer, persistence layer, infrastructure layer, AI layer and WebRTC layer.

ipation.

As mentioned earlier, the core of this architecture is hosted on a cloud platform. The network layer, using protocols such as WebRTC and HTTPS, ensures real-time, low-latency data transfer, which is essential for smooth interaction between the parties involved. Within this platform, the kernel provides common functionalities that facilitate the interoperability of the different modules of the system. In addition, the WebRTC layer manages videoconferencing sessions through signalling servers, TURN and STUN, ensuring stable communications.

The system also has a number of advanced functionalities managed by the AI layer, including video processing, metadata generation and summaries, and the integration of speech recognition and synthesis capabilities. These tools are used to optimise the interaction between the user and the specialist, and to record and analyse key information from the sessions. The infrastructure layer is responsible for user management, chat room creation and authentication, ensuring secure and controlled access to the system.

Finally, the generated and processed data is stored in a persistence layer, including session recordings and uploaded documents. This not only allows these resources to be reused for analysis and training, but also promotes the documentation of medical interactions, ensuring a transparent and efficient workflow.

4.2 MR Prototype

At the time of writing, we have developed a simple software prototype as a first approximation of the MR application that will run on the glasses worn by the GP. This application allows the user to visualise their

Figure 4: Screenshot of the current prototype of MR to support primary care physicians.

environment using the Meta Quest 3 helmet through a *pass-through* functionality. The application incorporates a hand tracking system which allows basic interactions that guide the GP through a simple medical protocol.

Each step of the protocol has a button that, when activated, displays an interactive canvas. This canvas allows the user to ask questions related to the current step of the protocol, which are spoken aloud. A LLM responds to these questions using a speech synthesis system. In addition, the canvas contains a dropdown menu to facilitate the selection of the mode of response generation. For steps with associated images, there is an additional button which, when activated, displays a third canvas with the corresponding images. Figure 4 illustrates the three canvases associated with a protocol step.

5 DISCUSSION AND CHALLENGES

The successful development and implementation of MRP-5G will require addressing a number of potential risks that could hinder its delivery or compromise the achievement of its stated objectives. These challenges are discussed below, along with the corresponding contingency strategies.

One potential challenge is the low level of commitment from medical staff, which could have a significant impact on the success of the project. Their active participation is crucial to ensure the practical relevance and acceptance of the proposed solutions. To address this, effective communication channels will be established to keep stakeholders informed of the project's progress. In addition, regular meetings will be organised, especially in the early stages, to encourage commitment and active participation.

Another challenge is the adaptation of medical staff to MR-based interfaces. Introducing this technology into clinical workflows may present usability and acceptance barriers for some professionals. To mitigate this risk, targeted training and interactive workshops will be conducted to familiarise medical staff with the technology. These activities will also provide a platform for gathering user feedback to refine interface designs and improve usability.

Ensuring reliable 5G connectivity is another key challenge. Network quality is critical for real-time, high-definition communication between medical professionals. To overcome potential connectivity issues, alternative solutions such as redundant links and complementary communication technologies will be explored. Partnerships with telecom operators will also be pursued to improve 5G coverage in the project deployment areas.

Dependence on specific MR devices is another risk, as hardware availability or compatibility could become problematic. To address this, the project will adopt open standards and use development libraries that enable interoperability between different devices. This approach will ensure flexibility and reduce the impact of potential changes in the hardware market.

Finally, unexpected analysis results could lead to misalignment with the aforementioned objectives. To manage this risk, a continuous monitoring and evaluation framework will be implemented. This proactive approach will enable early detection of data quality issues and allow timely adjustments to the methodologies to ensure reliable and actionable results.

6 CONCLUSIONS

In this position paper, we have proposed a technology platform called MRP-5G, designed to provide remote support in primary care through the use of MR and 5G-based communication infrastructures. The proposal addresses key clinical challenges such as limited access to specialists in rural areas and the need for technological solutions that promote efficient, interactive, and equitable care. This approach aims not only to optimise the quality of medical services, but also to reduce inequalities in access to care, particularly in regions affected by depopulation.

The MRP-5G architecture is organised into interrelated functional layers that, when implemented, will enable seamless communication between medical staff and remote users. The network layer manages connectivity through protocols such as WebRTC, ensuring low latency and high throughput, while the AI layer incorporates advanced video processing, transcription and summary generation tools to support real-time medical decisions. In addition, an infrastructure layer handles user authentication and the creation of virtual interaction spaces, while the persistence layer stores sessions and associated documents, providing an invaluable resource for further analysis and medical education.

In addition, this proposal has identified key areas of impact and opportunities for innovation through the implementation of MRP-5G. In particular, the ability to integrate real-time two-way communication, MR interaction, and an intelligent indexing system for recording and analysing clinical sessions stands out as a transformative approach. The latter functionality is intended to create a valuable resource for the training of medical staff, promoting knowledge transfer in academic and professional contexts.

ACKNOWLEDGEMENTS

This article is a result of the research project with ID SBPLY/23/180225/000182, entitled *Mixed reality-based platform on 5G infrastructure for remote support and diagnosis among nursing, general practitioners, and medical specialists* (MRP-5G), and funded by the European Union through European Regional Development Fund (FEDER) and by Junta de Comunidades de Castilla-La Mancha through Castilla-La Mancha Agency for Research and Innovation (INNOCAM).

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