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Revolutionizing Medical Processes Through Phygital Technology: a Multiple Case Study Approach

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Introduction

In our increasingly interconnected world, the line between the physical and digital is blurring: Phygital technology, the synergistic fusion of these two realms, is transforming industries, particularly healthcare, by opening new frontiers in how we interact with the world. Phygital technology seamlessly integrates physical and digital elements to create engaging, interactive, and personalized experiences (Kalra et al., 2023). Healthcare, inherently focused on human interaction and personalized care, faces unique digital-age challenges (Frascolla, 2020). Emerging technologies in the healthcare field, within the digital and virtual ecosystems, can facilitate hyper-personalized, data-driven care, leading to earlier disease detection, tailored therapies, and improved patient outcomes through individualized, predictive, and empathetic engagement (Paton et al., 2024). Phygital technology offers a powerful solution in this direction, promising to enhance the patient experience, streamline healthcare processes, and revolutionize diagnosis, treatment, and care. It leverages the power of the digital to enrich and amplify real-world interactions. This integration rests on three key pillars (Maci, 2024):

- Physical-Digital Integration: Phygital technology bridges the gap between the physical and digital using sensors, smart devices, and digital platforms. These interconnected elements create a dynamic ecosystem where information flows effortlessly between the real and virtual.
- Interactivity and Personalization: Phygital technology enables highly interactive and personalized experiences, tailoring the user journey to individual needs and preferences. This interactivity can be achieved through touchscreens, augmented reality, virtual reality, and other human-machine interfaces.
- Data Collection and Processing: Phygital technology facilitates the collection and analysis of vast amounts of data from diverse sources. This data provides valuable insights, informs better decision-making, and further personalizes the user experience.

Phygital technology has enormous potential to revolutionize healthcare, with applications spanning from patient management to cutting-edge medical research. It is possible to consider some examples; Phygital solutions empower patients through personalized health management apps, remote vital sign monitoring, and convenient telemedicine consultations. Besides, Phygital technology optimizes workflows through digital medical record management, efficient appointment scheduling, and streamlined administrative tasks; specifically Phygital tools support more accurate diagnoses and effective treatments through medical image analysis, surgical simulations, and robotic-assisted procedures. Moreover, Phygital technology accelerates research by enabling the collection and analysis of massive datasets, the creation of virtual organ and tissue models, and the simulation of complex clinical scenarios. In this way, Phygital technology represents a promising frontier for healthcare: its ability to merge the physical and digital worlds offers a unique opportunity to improve patient care, optimize healthcare delivery, and drive innovation in medical research. Drawing on the research conducted into the "Phygital Twin Technologies for innovative Surgical Training & Planning" of the Rome Technopole program, this poster presents a first artifact solution related to the phygital

technology was analysed, allowing to investigate the cross-advantages of a physical product with its digital twin. For this type of artifact, it will be necessary to understand how to guarantee the immediacy, immersion and interaction of users with respect to the clinical case for which the phygital experience is designed.

Data & Method

A multiple case study was conducted with experts of this technology at the Sapienza, University of Rome. This analysis informed the development of a framework demonstrating what features the phygital phantom product needs for its architecture in order to be a valid product that can be used not only in the real world and offline mood but also in an online integration perspective in a metaverse world or on-line mood. A Design Science approach guided our analysis. Design Science approach is a problem-solving approach that involves designing, implementing, and evaluating artifacts to address specific needs, bridging the gap between research and practice (Tarpey and Mullarkey, 2021; Guggenberger et al., 2020). Our research followed the Design Science approach process, including defining the ecosystem and problem space, which involves identifying key actors (e.g., individuals and organizations), applications, and goals (Centobelli et al. 2021; Cerchione et al., 2022). A well-defined ecosystem enhances the relevance of the resulting artifact. Our knowledge base, comprising established methodologies and theoretical foundations, provided the necessary research context, supporting the qualitative findings and enhancing the quality and effectiveness of the framework found (Hevner et al., 2004). The framework's value is assessed based on its relevance to real-world business requirements.

To collect useful information to define the ecosystem and basic knowledge, data collections were carried out using a mixed methodology, the Analytical Hierarchy Process (AHP) and Fuzzy set theory (FST). Specifically, we were asked to evaluate different aspects that emerged in the literature, with the possibility of adding others related to the interviewees' experience. In this way, it was possible to dynamically define and evaluate all the aspects that emerged from the surveys carried out. Using a mixed methodology, AHP/FST allows us to integrate additional variables during the process without losing the data collection that was previously carried out. The old respondents had to answer only the questions relating to the new variables without returning to the answers already given.

Results and conclusions

The resulting framework offers an innovative approach to integrating diverse medical requirements, coordinating stakeholders and activities, and seamlessly connecting with existing systems to automate and optimize both local and remote healthcare workflows. Key benefits of implementing the Phygital technology in healthcare include personalized health data tracking, advanced analysis of patient clinical data, and the potential for eliminating paper-based medical records. Furthermore, training activities, users' medical skills and knowledge diffusion of healthcare best practices result the main advantages that this technology can offer to the ecosystem where it is adopted. However, challenges remain (Paquin et al., 2023), particularly regarding the management of sensitive data flows and the potential risks to user privacy and ethical considerations (Koohsari et al., 2023). Successfully integrating the Phygital technology into healthcare will require addressing these challenges and ensuring secure and ethical interactions between doctors, patients, and devices.

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