SOSIA: a modular system for developing Digital Twins to support personalized healthcare

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***Abstract*—This paper proposes a conceptual framework for the creation of personalized digital twins, called SOSIA, which are conceived as realistic digital avatars capable of faithfully representing an individual's identity, characteristics, and psycho-physical state. The primary objective is to support vulnerable populations, such as the elderly or individuals with cognitive impairments, in their interactions with the healthcare system and in managing personal well-being. The proposal integrates emerging technologies, including Artificial Intelligence, Generative AI, and Virtual Reality, opening new perspectives in personalized digital representation. The paper presents the initial vision of the framework, its scientific motivations, and potential application scenarios.**

***Index Terms*—Digital Twin, Virtual agents, Health care, Artificial Intelligence.**

I. Introduction

Modern medicine is confronted daily with the high interindividual heterogeneity that characterizes patients, often making a standardized therapeutic approach insufficient [6]. An attempt to respond to this challenge can be observed in precision medicine and personalized medicine, which integrate genetic, environmental, behavioral, and clinical variables to define an individual therapeutic path [1] [7].

Despite numerous advances, the practical and comprehensive management of clinical information remains a challenge for both healthcare professionals and patients. In particular, in fragile populations (such as the elderly, subjects with cognitive impairments, or those with memory deficits), it is often complex to provide an accurate and structured account of their clinical conditions, the symptoms presented, and the relevant anamnestic information, thus compromising the diagnostic and therapeutic process. The development of emerging digital technologies - including artificial intelligence (AI), big data, cloud computing, and virtual reality (VR) - offers new opportunities to overcome these critical issues, enabling digital patient modeling through the Digital Twin (DT) paradigm, initially developed in the engineering field and now progressively extended to the biomedical context [5] [3].

The concept of DT in medicine aims not only to reproduce the physiopathological parameters of an individual faithfully but also to simulate the evolution of diseases and responses to treatments in real time, thanks to the continuous integration of multimodal data [4].

The SOSIA framework is part of this emerging context, which proposes further extending the concept of the digital twin by integrating identity, cognitive, and communication dimensions to provide active support to fragile patients in managing their clinical and care pathways.

II. Related works

The digital twin paradigm applied to medicine has progressively gained relevance due to its ability to integrate heterogeneous data — including genomic, phenotypic, clinical, and environmental data — to represent and simulate the dynamic state of an individual [3] [4]. Several studies have already proposed DT models for simulating specific organs, such as the heart, the lung, or the musculoskeletal system, providing predictive tools to support clinical decisions [9] [11].

In parallel, recent advances in multimodal generative models now enable us to move beyond mere physiological modeling to achieve a more holistic representation of the individual. Generative AI models, such as large language models (LLMs), generative adversarial networks (GANs), and neural speech synthesis systems, enable us to create personalized digital representations that can reproduce an individual's visual appearance, verbal expressions and communication style [10] [8]. These capabilities are particularly promising for creating digital avatars to support doctor-patient communication, which is already being tested in contexts such as psychological support, therapeutic coaching, and chronic management [2].

However, to date, most of these systems remain highly generalized, lacking real in-depth identity modeling and personalized cognitive memory.

The SOSIA framework aims to help fill the gaps currently present in the use of healthcare technologies by integrating personalized generative models, adaptive cognitive computational architectures and immersive VR interfaces to create digital avatars that function as true digital representations of individual identity. Unlike conversational agents, the digital twins proposed by SOSIA will be designed to store, interpret and consistently update patients' clinical and biographical information, enabling personalized and contextualized interactions and supporting long-term continuity in healthcare delivery.

III. Methodology

The SOSIA framework is configured as a modular and multi-level architecture designed for the progressive construc-

tion of personalized digital twins aimed at supporting vulnerable populations. The first level of the framework involves the acquisition of multimodal data through the systematic collection of heterogeneous data relating to the individual. This acquisition includes static and dynamic images of the face and body, as well as voice recordings for the prosodic and timbric characterization of the digital twin. Additionally, it involves structured biographical interviews aimed at reconstructing the patient's medical history and life context. Subsequently, based on the provided data, a generative identity modeling approach is planned, utilizing multimodal generative artificial intelligence techniques to create a personalized digital avatar. In this phase, the visual features, synthetic voice, facial expressions, and communication profile of the avatar are explicitly generated and calibrated to match the user's identity characteristics. The generative component is accompanied by the construction of a computational cognitive memory, understood as an adaptive system capable of longitudinally integrating clinical information, updated anamnesis, communication preferences, and cognitive vulnerabilities, thus providing a dynamic and coherent representation of the person. Finally, the framework integrates a mediated interaction interface, which allows the digital twin to operate as a cognitive intermediary between the patient and the various healthcare or assistance interlocutors. The interaction occurs in virtual reality or mixed reality environments, enabling bidirectional communication and continuous access to relevant information. Although the project is currently in its infancy, SOSIA's modular structure is designed to make the system usable in multiple areas, including geriatric support, advanced telemedicine, cognitive rehabilitation, and the multidimensional management of complex chronicity.

IV. Discussion and Conclusions

The SOSIA framework is proposed as an integrated system for creating personalized digital avatars, capable of representing not only the physiological characteristics of the individual but also the cognitive, psychological, and biographical dimensions that constitute personal identity. Through multimodal data acquisition, generative identity modeling, the construction of a computational cognitive memory, and the implementation of immersive interfaces for interaction, SOSIA aims to support frail patients in complex healthcare interactions, facilitating communication, understanding, and management of clinical information.

The development of personalized digital twins, such as those proposed in the SOSIA framework, opens up relevant application perspectives for personalized medicine but, at the same time, raises a series of complex challenges of a technical, clinical, and ethical nature. On the technological level, the primary challenge lies in ensuring the reliability and internal coherence of multimodal generative models while maintaining privacy protection, transparency in the governance of sensitive data, and the robustness of the systems in terms of cybersecurity. The integration of these models requires an interdisciplinary synergy involving not only engineering and computer science skills but also cognitive neuroscience, clinical psychology, and bioethics. From a clinical perspective, the effectiveness of the framework will need to be evaluated through controlled longitudinal studies, which not only measure the impact on traditional health outcomes but also analyze the degree of acceptance, trust, and perception of realism among both patients and healthcare professionals involved. Looking ahead, the subsequent developments of the SOSIA project will focus on optimizing individual data acquisition pipelines, designing and implementing the first functional prototypes, and launching pilot studies in real clinical contexts for the first empirical validation of the system.

References

[1] Euan A Ashley. The precision medicine initiative: a new national effort. *Jama*, 313(21):2119–2120, 2015.

[2] Timothy Bickmore, Ha Trinh, Reza Asadi, and Stefan Olafsson. Safety first: conversational agents for health care. *Studies in conversational UX design*, pages 33–57, 2018.

[3] Koen Bruynseels, Filippo Santoni de Sio, and Jeroen Van den Hoven. Digital twins in health care: ethical implications of an emerging engineering paradigm. *Frontiers in genetics*, 9:31, 2018.

[4] Jorge Corral-Acero, Francesca Margara, Maciej Marciniak, Cristobal Rodero, Filip Loncaric, Yingjing Feng, Andrew Gilbert, Joao F Fernandes, Hassaan A Bukhari, Ali Wajdan, et al. The 'digital twin'to enable the vision of precision cardiology. *European heart journal*, 41(48):4556–4564, 2020.

[5] Michael Grieves and John Vickers. Digital twin: Mitigating unpredictable, undesirable emergent behavior in complex systems. *Transdisciplinary perspectives on complex systems: New findings and approaches*, pages 85–113, 2017.

[6] Margaret A Hamburg and Francis S Collins. The path to personalized medicine. *New England Journal of Medicine*, 363(4):301–304, 2010.

[7] Leroy Hood and Stephen H Friend. Predictive, personalized, preventive, participatory (p4) cancer medicine. *Nature reviews Clinical oncology*, 8(3):184–187, 2011.

[8] Tero Karras, Samuli Laine, and Timo Aila. A style-based generator architecture for generative adversarial networks. In *Proceedings of the IEEE/CVF conference on computer vision and pattern recognition*, pages 4401–4410, 2019.

[9] Steven A Niederer, Yasser Aboelkassem, Chris D Cantwell, Cesare Corrado, Sam Coveney, Elizabeth M Cherry, Tammo Delhaas, Flavio H Fenton, Alexander V Panfilov, Pras Pathmanathan, et al. Creation and application of virtual patient cohorts of heart models. *Philosophical Transactions of the Royal Society A*, 378(2173):20190558, 2020.

[10] Aditya Ramesh, Prafulla Dhariwal, Alex Nichol, Casey Chu, and Mark Chen. Hierarchical text-conditional image generation with clip latents. *arXiv preprint arXiv:2204.06125*, 1(2):3, 2022.

[11] Marco Viceconti, Peter Hunter, and Rod Hose. Big data, big knowledge: big data for personalized healthcare. *IEEE journal of biomedical and health informatics*, 19(4):1209–1215, 2015.