https://doi.org/10.51408/issi2025_185

How far are we from understanding phygital healthcare convergence? Building an AI knowledge map grounded in bibliometric metadata

Cinzia Daraio[1], Simone Di Leo[2]

[1]*daraio@diag.uniroma1.it*,[2]*dileo@diag.uniroma1.it*
Department of Computer, Control and Management Engineering Antonio Ruberti (DIAG), *Sapienza* University of Rome, Via Ariosto 25, Rome, 00185 (Italy)

Introduction

Initially prevalent within the marketing domain, the increasing convergence of the physical and digital realms, commonly termed the "*phygital*" concept (Batat, 2024), is revolutionizing various sectors, including healthcare. This influence is exemplified by prominent initiatives in this field such as the Rome Technopole project "*Phygital Twin Technologies for Innovative Surgical Training & Planning"* using the *phygital* concept by developing digital and physical technologies for planning and training surgeons. The *phygital* paradigm creates hybrid experiences blending real-world interactions with virtual ones, offering new opportunities for learning and practice. This can be done using various technologies like Digital Twins (DTs), Augmented Reality (AR), Virtual Reality (VR), and Artificial Intelligence (AI). DTs and virtual representations of physical entities, processes, or systems, are key elements in this context, providing simulated environments for training, planning, and analysis. However, the *phygital* concept extends beyond DTs, encompassing a broader ecosystem of technologies. This research delves into this ecosystem using an innovative methodology that combines traditional bibliometric metadata (author's keywords) with the power of AI to create a knowledge map (KM) on the *phygital* concept in healthcare to find convergence relationships of the different concepts. KMs are graphical representations of knowledge, where nodes represent concepts and edges represent relationships between them. KMs can help researchers to identify areas and research landscapes within a specific field or topic. Bibliometric analysis, which has traditionally relied on citation counts and co-occurrence analysis, is commonly used to understand research landscapes. However, this approach has various limitations (see e.g. Haustein & Larivière, 2014). This research addresses this gap by utilizing AI-generated KM while concurrently preserving bibliometric source metadata. To create the KM, we leverage the capabilities of the AI by Google called Gemini 2.0 (G2, https://gemini.google.com/app). Base the KM creation to the bibliometric metadata ensures the reliability of the generated knowledge by grounding it in verifiable data sources and mitigating potential biases that may arise from exclusive reliance on AI-
only information. This approach offers a more comprehensive perspective than conventional bibliometric methods by enabling the identification of prominent research areas, subtle relationships and emerging subfields on the *phygital* in the healthcare context.

Method

This study employed a two-stage process to construct the KM of the *phygital* concept within the healthcare field. The first stage involved a systematic search within the Scopus database (https://www.scopus.com/) to retrieve the bibliometric metadata. The query was conducted on the TITLE-ABS-KEY fields. The search combined keywords related to digital representations ("Digital twin", "Digital twins", "Digital phantom", "Digital phantoms", "phygital" and "physical twin"), training applications ("practice", "training", "teaching", "didactic", "Didactic purpose", "Surgical training" and "Robot assisted surgery"), and the healthcare domain ("healthcare", "health care" and "medical"). The search was done on January 16, 2025. From the retrieved articles, author-supplied keywords were extracted. The second stage used the retained keywords as input for G2, using *Termboard* (https://termboard.com/app#/ generated prompt) to identify the relations between these keywords and the *phygital* concept. To contextualize the analysis, the definition of *phygital* provided in the Introduction Section was explicitly provided to G2 before the identification of the relations. This step was crucial to guide the AI's exploration of the connections within the extracted keyword set, assisting the construction of the KM.

Results and conclusion

From the Scopus search, we obtained 157 articles with author's keywords information. The initial keyword analysis of these articles yielded a total of 712 keywords. To ensure relevance and focus on core concepts, only keywords appearing in at least two distinct articles were retained for subsequent analysis. A final refined set of 26 keywords (excluding "*phygital*") was kept. These 26 keywords and the "*physical*" keyword were then ingested into G2 to create the final KM (presented in Figure 1). Several key relationships emerge:

Phygital as a Bridge: A primary function of *"phygital"* as depicted, is to bridge the digital and physical realms. This bridging role is explicitly linked to "simulation", "digital twin", "training" and "medical education." Phygital environments enable enhanced training and educational experiences by integrating digital representations and simulations with tangible, physical elements. This is further reinforced by the connection to "computational modelling" indicating the use of digital models to inform and interact with physical processes within a phygital context.

Phygital in Healthcare: The map positions "phygital" firmly within the domain of "healthcare" and, more specifically, within "Phygital Healthcare". This sub-concept highlights the application of phygital principles to healthcare practices. Relationships with "digital health", "telehealth ecosystem" and "remote patient monitoring (RPM)" indicates that phygital approaches are integral to the evolving landscape of digital healthcare delivery.

Technological Enablers of Phygital: Several technological concepts are shown to enable or contribute to the creation and function of phygital environments. "Technology" itself forms a broad category, encompassing "artificial intelligence", "machine learning" and "deep learning". These AI-related technologies are shown to power "AI-Powered Diagnostics" and contribute to "precision medicine", suggesting that AI plays a critical role in analyzing data and personalizing treatments within phygital healthcare settings. Furthermore, "3D printing" is represented as enabling the "physical manifestation of digital designs", a core component of creating tangible elements within a *phygital* environment. The connection to "virtual reality" and "metaverse" indicates that immersive digital environments are also key components of certain *phygital* applications, potentially offering virtual spaces for training, simulation, or patient interaction.

Contextual Factors: contextual factors influencing the development and adoption of *phygital* approaches are present in the map. "COVID-19" is linked to "accelerated adoption of digital solutions", suggesting that the pandemic has spurred the development and implementation of phygital technologies in healthcare.

In conclusion, the generated KM provides a valuable overview of the multifaceted nature of the *phygital* concept and its diverse applications within healthcare. It highlights the role of phygital as a bridge between the digital and physical worlds, emphasizing its potential to enhance training, education, and healthcare delivery. The map also underscores the importance of enabling technologies such as AI, 3D printing, and virtual reality in creating effective *phygital* environments. Withing this context, the Rome technopole project appears to be fully aligned with the guidance provided by KM. The proposed innovative methodology answered the main research question of this article, laying the foundation for a first AI KM creation grounded in bibliometric metadata. Although this methodology shows interesting results, limitations must be acknowledged. The first concerns the use of the G2 tools, which, despite being one of the most advanced AIs, still has biases deriving from its training process and available information. The further limitation concerns the prompt generated using *termboard* can be improved by using advanced prompting techniques such as few shots (Kaplan et al., 2020) or chain of though (Wei et al., 2022).

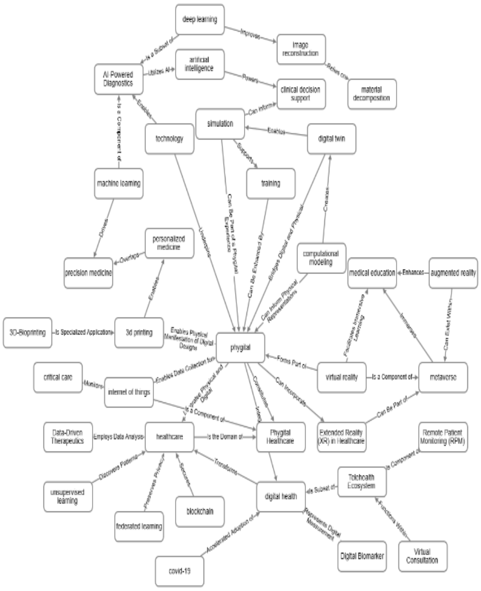

Figure 1. AI knowledge map on phygital in the healthcare sector, grounded on bibliometric metadata.

Acknowledgments

The poster is part of the Research Projects “Phygital Twin Technologies for Innovative Surgical Training & Planning (ECS 0000024 – Rome Technopole)”.

References

Batat, W. (2024). What does phygital really mean? A conceptual introduction to the phygital customer experience (PH-CX) framework. Journal of Strategic Marketing, 32(8), 1220–1243.

Haustein, S., & Larivière, V. (2014). The use of bibliometrics for assessing research: Possibilities, limitations and adverse effects. In Incentives and performance: Governance of research organizations (pp. 121–139). Springer.

Kaplan, J., McCandlish, S., Henighan, T., Brown, T. B., Chess, B., Child, R., Gray, S., Radford, A., Wu, J., & Amodei, D. (2020). Scaling laws for neural language models. ArXiv Preprint ArXiv:2001.08361.

Wei, J., Wang, X., Schuurmans, D., Bosma, M., Xia, F., Chi, E., Le, Q. V, & Zhou, D. (2022). Chain-of-thought prompting elicits reasoning in large language models. Advances in Neural Information Processing Systems, 35, 24824–24837.