

## **Abstract**

The shift to Industry 5.0 has resulted in a greater emphasis on truly human-centered paradigms, in which technological advancement is oriented not only toward automation and efficiency, but also toward improving human abilities, well-being, and inclusion. In this context, the paradigm of the Internet of Ability (IoA), proposed as an evolution of the Internet of Things (IoT), shifts the focus from the interconnection of smart objects to the connection and amplification of people's abilities.

Extended Reality (XR) technologies represent the preferred technological infrastructure for implementing this paradigm. Thanks to their ability to create immersive, interactive, and multisensory environments, XR not only allows complex data to be visualized and manipulated intuitively, but also enables the design of personalized and accessible experiences that can respond to cognitive, physical, social, and emotional users' needs. In this perspective, XR provides an enabling interface that allows the implementation of the IoA principle of enhancing individual abilities through flexible and adaptive technological solutions.

This research aimed to define, develop, and validate an IoA framework based on XR technologies, conceived as a methodological and technological ecosystem to augment and support human capabilities. The adopted approach was experimental and progressive, based on case studies conducted mainly in the healthcare and cultural heritage sectors, allowing the exploration of the framework applicability in contexts that are very different from each other: on the one hand, highly structured and sensitive healthcare scenarios, in which XR supports doctors and patients in clinical practice; on the other hand, cultural contexts oriented towards education, engagement, and heritage valorization, in which XR increases accessibility and encourages public involvement. In both areas, the case studies made it possible to test the framework with different types of users (doctors, patients, engineers,

museum visitors), highlighting its flexibility and adaptability to diverse roles, skills, and objectives.

The main contribution of the thesis is the outline of a conceptual and operational multilayer model that demonstrates how XR can serve as the basic architecture for the implementation of IoA, as well as the operational steps for guiding the implementation of XR-based solutions that comply with its principles. Through their ability to integrate artificial intelligence modules for automatic feedback, multisensory interfaces that combine spatial audio and haptics modalities, and inclusive and adaptable design strategies, XR enables the construction of a dynamic and modular ecosystem that can be tailored to different domains and users' requirements. Furthermore, a practical example of the framework's application is provided, developing a collaborative XR planning platform for cranio-maxillofacial surgery that implements the framework at all levels, clarifying how the proposed XR-IoA framework model guides concrete design choices while preserving modularity and multi-platform adaptability.

This work is in an emerging field and should be read with its inherent limitations in mind. Technological maturity remains a limitation: despite the use of cutting-edge components, the pace of innovation in XR, Artificial Intelligence (AI), and networking may soon outpace specific implementations. Furthermore, the current XR ecosystem also features fragmented standards and limited interoperability, complicating portability, cross-platform reproducibility, and long-term maintainability. Second, experimental validation has so far been conducted in controlled settings and on a limited scale; larger, in situ studies are needed to confirm effectiveness in real-world contexts and settings.

From an infrastructure perspective, strengthening interoperability through open interfaces and exchange formats, and cross-platform testing are needed to improve robustness and transferability. From a methodological perspective, the integration of advanced behavioral analysis models can support in-depth personalization and partially automate the refinement process to tailor solutions and interfaces to individual users based on each person's interaction styles, technological familiarity, emotional responses, and cognitive profiles. Together, these advances would extend the XR-IoA framework from a generally inclusive environment to a truly personalized and evolutionary system that not only connects but also learns from people and reshapes itself around them to support the development of their capabilities.