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Multiscalar Digital Twin. Step Representation towards Urban Multiverse

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Abstract

In this paper we describe the representation of the environment where the interaction between user and digital models in architectural and urban settings in the design, construction and subsequent maintenance phases. The purpose lies in establishing scenarios for an evolution of the concept of the space of user-model interaction in a fully virtual digital space containing both. The paper lists the main limitations of current tools related to the fruition of models in the field of construction or urban data reading, with a curious look at immersive reality environments, more developed towards gaming or other realities where it is the representation of the space that becomes the means for interaction with objects. To do this, the paper is divided into 3 parts in which concise graphic diagrams indicate quick summaries: analysis and schematization of the user/architectural model or user/urban model relationship with a brief repertoire of modalities and possible augmented technologies; analysis of the main interaction environments comprising users and objects where the representation of space plays a key role in the development of actions; opportunities in the field for the representation of new interaction spaces, limitations and levers for its growth, and methodologies necessary for its fulfillment.

Keywords
User interactions, Urban space, City Information Modeling

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Introduction: analysis and schematization of the user/architectural model or user/urban model relationship

Digital fruition platforms of 3d models are virtual environments that allow users to access, manipulate, and interact with 3d models in a digital format [Stephenson 1994]. These platforms are becoming increasingly popular for the development of 3d models for a wide range of applications, such as 3d printing, 3d visualizations, and 3d simulations. As these platforms continue to evolve, there is potential for them to become a part of the metaverse, a virtual world where multiple users can interact and be present in the same environment at the same time (fig. 1). This could provide a unique platform for creative collaboration and further development of 3d models and other forms of digital media. It then becomes of cardinal importance for the purpose of building control to understand how the concept of digital twin can be declined at different scales of representation, from building to urban. While in the former case there is already an established literature [Deng et al. 2021], with metaverses the possibilities for exploration are manifold because of the very recent sedimentation of these technologies (fig. 2). As the technology behind these platforms continues to improve, the possibilities of what can be achieved with them are endless.

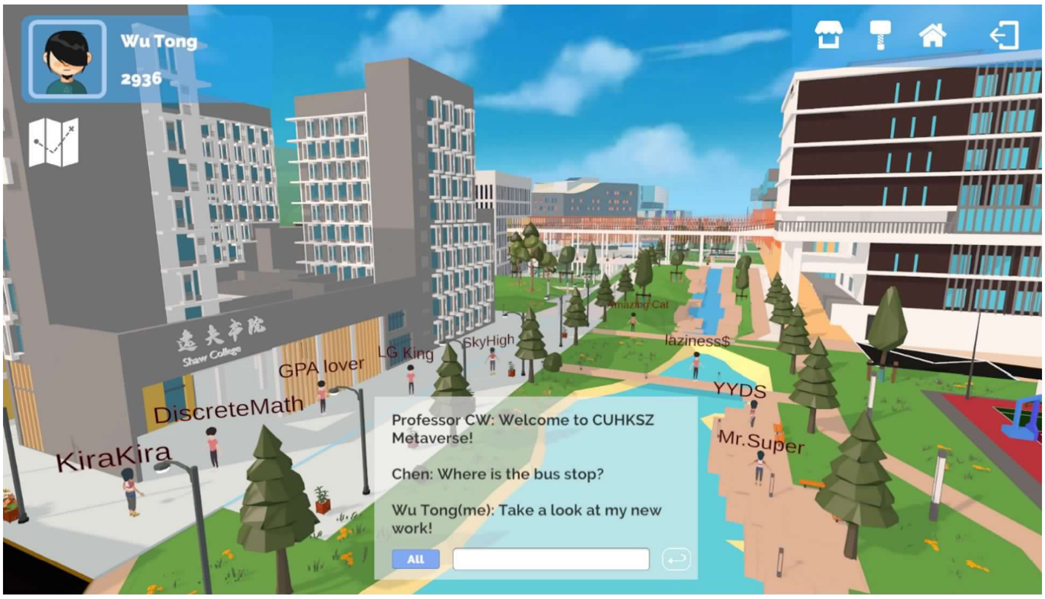

Fig. 1. The Chinese University of Hong Kong, Metaverse representation of a physical space with user-related services and interaction. Braud et al. 2022.

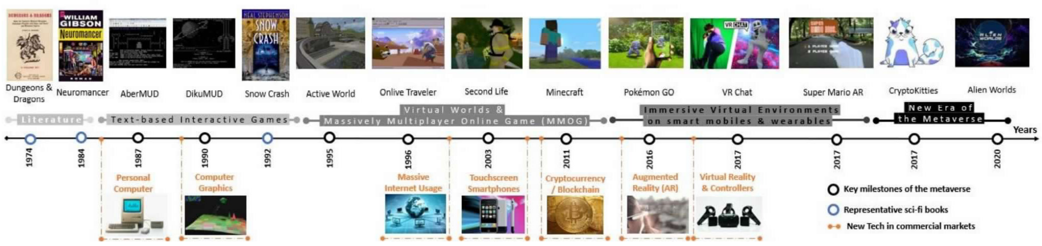

Fig. 2. Timeline of the metaverse development and key milestones that produced the current technological environment. Khan 2020.

Three-dimensional space representations as tools for regulating user-model relationships - 3DInformed building representation in shared environments

The architectural model and related information have increasingly become the object of study in the aspects of collaborative interaction for multiple users, useful for a facilitation of the process of construction and maintenance of architectures. The areas that best accommodate these instances currently refer to interaction platforms mainly organized by the same software houses for a fruition of their products: these are environments that do not constitute a true ACDat, (as defined by the UNI 11337-5:2017 standard i.e. an IT infrastructure for the collection and organized management of data that guarantees accessibility, traceability, revision history, query flows, access guarantees) but maintaining the constraint of the authorship of data allow the fruition to users with similar profiles, owners of the same licenses. ACDat, is the english equivalent for CDE [Daniotti et al. 2020]: Common Data Environment (fig. 3), an acronym for Data sharing Environment, a digital environment for the organized collection and sharing of data, digital models included based on an information infrastructure whose sharing is governed by precise security systems.

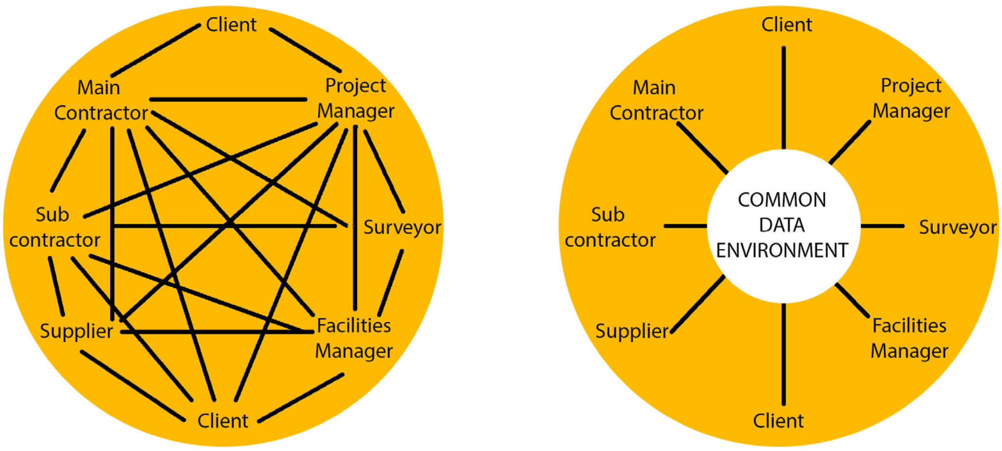

Fig. 3. Common Data Environment concept- Organization of the fruition in a platform. The BIM Delivery Group for Scotland, Scottish Future Trust (SFT).

If we think about collaborative platforms based on these features, we can list some of them such as BIM 360 Autodesk©: it is an integrated cloud-based platform that helps streamline the construction process from pre-construction to operations and maintenance. It is equipped as a platform to share visualization of 3D models in a normal data sharing environment, where links and cross-references lead to different data sheets or a visualization of the 3D model. The framework is built for collaboration among different users on a federation model of architectural and plant models. Over time, other platforms have grown that have sought to introduce model management that meets interoperability requirements among software, expanding the possibility of its use. Among them usBIM. platform ACCA ©. The goals are always the same with respect to their operation: to have a cloud infrastructure with integrated functions for online viewing, management and sharing of BIM files of any format and size, a common environment for collaborative work with high security standards to ensure efficient management of BIM projects.
From this point of view, the past few years have been a growth of cloud-based platforms for model management; the platform is the typical solution adopted to facilitate the use of models even for less experienced users. Many of these represent simple databases where

the focus is not so much the interaction between multiple users but the storage of models and related documents to have the possibility to work on separately. 3D representation turns out to be a secondary issue with respect to fruition remaining mainly related to the object of study, the digital model. Although the use of BIM platforms is mainly directed toward the management of contemporary building stock, it is worth mentioning a particular use of these in the Heritage BIM environment. There are powerful tools for preserving and enhancing the cultural, social and economic value of heritage assets (fig. 4). These web platforms can interact with users through cloud technology to share building geometric and semantic data. Among experiments in this direction [Maietti et al. 2017] defines procedures for surveying and 3D modeling of complex buildings. The aim is to make digital documentation of cultural heritage more accessible through semantic enrichment of 3D models, which will be part of the overall documentation process [Balzani, Maietti 2017].

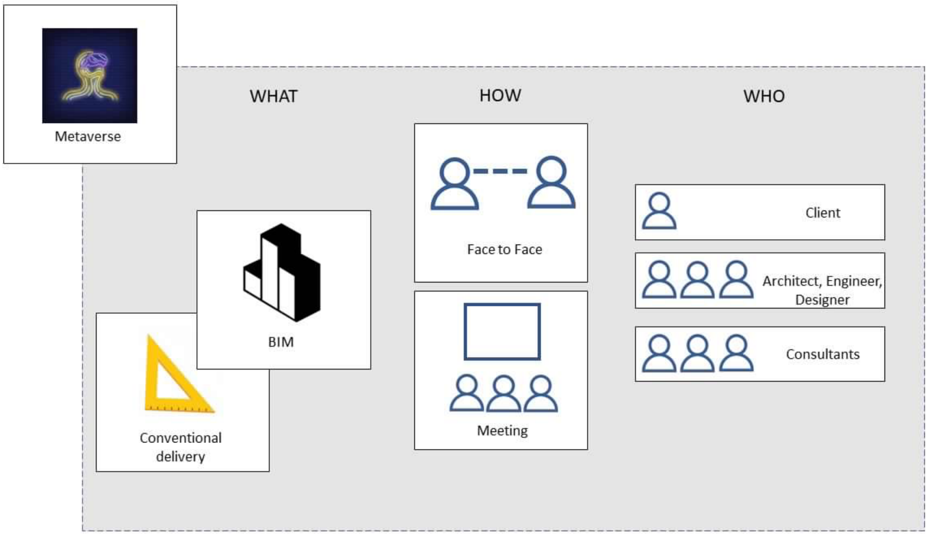

Fig. 4. Relationship between BIM systems, the metaverse in connection with the time parameter. The relationships between different technologies used, such as H-BIM for the past, BIM for the present, the metaverse and predictive algorithms for the future are schematized Huang et al. 2022.

CIM representation in shared environment

Architectural model management platforms, environments for sharing both models of new buildings and the heritage field, however, belong to systems of partial representations, with interactions limited to the scale of the building. They do not summarize within them data receiving activities that can change their appearance, they do not have IoT or applied sensor activities. In addition, they are only usable from desktops; they do not offer virtual sharing environments. Representations at a larger scale, multiple buildings or urban scale environments when informed are linked to another field of research usable on different representation platforms than those more proper to BIM. The answer to these analysis needs is the concept of city information modeling (CIM), a methodology of urban planning that aims to create a digital representation of a city's physical and functional characteristics. It is an approach to planning and decision-making that integrates data, processes, and technology to better understand, analyze, plan and manage a city's resources and services. Its technology is empowered by the BIM, digital twin, geographic information system (GIS), Internet of Things and other technical foundations [Huang 2022]. CIM is a way to capture and visualize the complexity of a city in a digital format, allowing planners and decision makers to make better decisions and better plan for the future. This information is then used to create a

3D digital model of the city, which can be used to analyze the city's land use, transportation networks, infrastructure, and other features. This model can then be used to identify potential opportunities for development, such as new roads or parks, or to identify potential risks, such as flooding or traffic congestion. CIM can also be used to develop strategies for urban planning. CIM is becoming increasingly important for urban planners, as it provides a way to better understand and manage a city's resources and services. It is also a valuable tool for decision makers, as it allows them to make informed decisions and better plan for the future.
Tools that work within this environment are less common than BIM instruments. Most of them are in a development phase, but two notable examples are: Virtual City Systems (VCS), Landscape Information Modeling (LIM).
Virtual city systems (VCS) (fig. 5) are computer-based simulation software that can create a digital representation of a real-world urban environment. It is used to simulate the behavior of the physical and social components of a city, such as land use, transportation, and population. VCS can be used to analyze the feasibility of urban planning initiatives, as well as to inform policy decisions related to urban growth and development. It is used to examine different scenarios and to identify potential impacts on the environment, infrastructure, and public health. VCS can also be used to identify the best locations for new businesses and residential developments. Finally, VCS is also used to promote sustainable development initiatives, such as green infrastructure and efficient energy systems. Notable Tools belonging to this family are: VC Planner, VUC Database, VC Blastprotect and Building Reconstruction.
LIM (Landscape Information Modeling) is an innovative approach to landscape planning developed by Land Architecture firm. It combines the existing GIS data, environmental data,

Fig. 5. Model of the city of Berlin made using the City Information modeling (CIM) methodology. The used software platform is Virtual city systems (VCS), which integrates BIM, GIS and Internet of Things. Huang et al. 2022.

and landscape visualizations to model the landscape in 3D and provide detailed information about the landscape. It allows for the integration of local government, industry, and public participation to better understand the landscape and create better plans for its future. The LIM process helps decision makers to understand the effects of their decisions on the landscape and predict potential future scenarios. LIM models are used in a wide range of applications, such as urban and regional planning, environmental impact assessment, and water resource management. The Digital Twin methodology is still little explored at the urban scale, although a few case studies, such as that of the city of Herrenberg [Dembski et al. 2020] are paving the way for more widespread evolutions The use of CIM tools has expanded the boundaries of the control area of BIM processes. However, there are structural limitations in the user-model interaction of CIM tools that can be overcome by adopting more innovative spatial representation methodologies, the metaverses.

Metaverse representation

In the study of the relationship between user and model, a form of representation that allows multiscalar fruition the metaverse ecosystems is emerging (fig. 6). In recent years, more and more in-depth studies describing the benefits and limits of these types of systems are becoming more widespread [Khan Hussain 2020]. For the purpose of this paper, studies have been analyzed that relate users to urban models that are not limited to a simple perceptual exploration of virtual environments, but rather give the opportunity to actively interact with them. CityDAO, Meta-Seoul, and e-Residency are examples of interactive metaverse. A prime example is the experimentation currently underway in Seoul, with Meta Seoul (fig. 7) [Metabus Seoul 2023].By 2026, the Meta-Seoul government plans to provide its residents with the same legal governmental functions both in the virtual and real worlds. Additionally, they are aiming to establish a city-wide IoT and robot service system to connect public services, such as transportation, logistics, and water supply, between the two. An interesting experimentation of user/model interaction is the simulation of the Chinese University in Hong Kong, [Braud 2022] (fig. 8), where real university is replicated in a 3d model where students can interact with academic services with their avatar.The mentioned metaverses, although in the experimental stage, are important because they form the basis for a multiscalar approach to the interaction between users and space.

Features of representative Metaverse example

Metaverse Example			Blockchain	AV/VR	DT	UGC	AI
MMORPG	World of Warcraft		x	x	x	v	AI enemies
	Grand Theft Auto Online		x	x	x	v	AI in Rockstar advanced game engine
	Final Fantasy XIV		x	x	x	v	Ai enemies
	Pokemon GO		x	v	v	v	Plan route more strategically
	Animal Crossing: New Horizon		x	x	x	v	AI NPCs
	Second Life		x	x	x	v	AI NPCs
	Minecraft		x	v	v	v	Platform to train AI
	DragonSB		v	x	x	v	Ai enemies
Application of the Metaverse	Smart Cities	Metaverse Seoul	v	v	v	v	AI NPCs
		Barbados Metaverse Embassy	v	v	v	v	AI NPCs
	Entertainment	Altspace VR	v	v	v	v	AI NPCs
		Decentraland	v	v	x	v	AI NPCs
	Education	Xirang	v	v	v	v	AI NPCs
		CUHKSZ	v	x	v	v	AI NPCs
	Work	Horizon Workrooms	v	v	v	v	Tools for designing virtual content
		Microsoft Mesh	v	v	v	v	Tools for avatars, holoportation, and spatial rendering
	Healthcare	Telemedicine	v	v	v	v	Data analysis and collaboration

Fig. 6. Metaverse examples in relation with Blockchain, Augmented / Virtual Reality, Digital Twin and Artificial Intelligence. Xu et al. 2020.

The ultimate goal of this paper, in light of the state of the art of the three steps of analysis, the building, the city, and the metaverse, respectively, is to lay the foundation for understanding whether it is possible to create a real-time multiscalar urban digital twin platform (fig. 9).

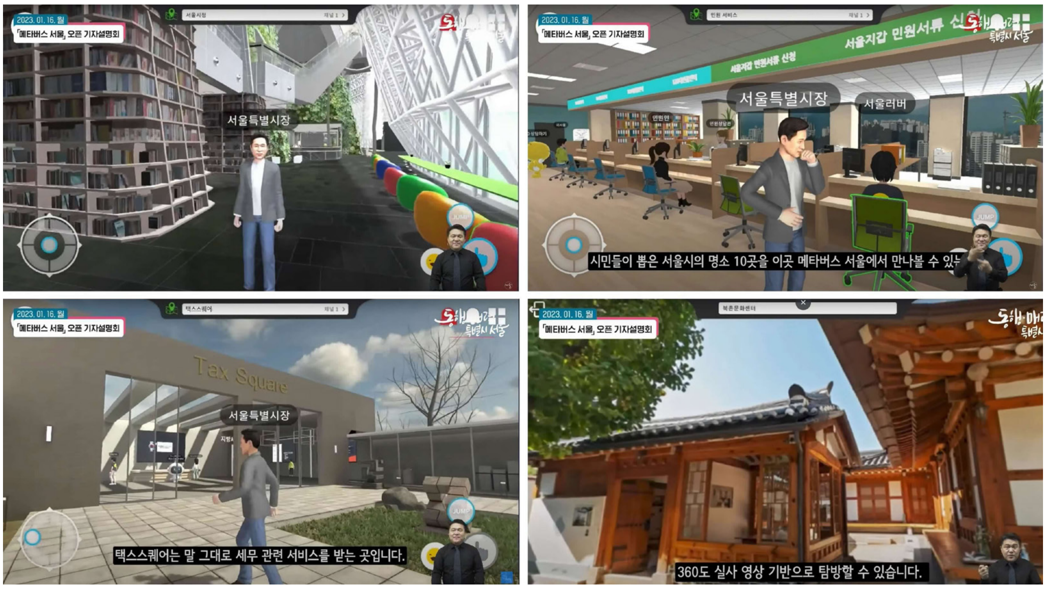

Fig. 7. Metaverse Seoul, User integration is carried out in a three-dimensional digital model of the city of Seoul. A selection of services is shown clockwise from the upper left corner. The City Hall building in which there are administrative services and meeting rooms. The tourist information office. A tourist site. The tax payment office, where tax consultations can be obtained. Metabus Seoul 2023.

Methodology limits and future developments

Working methodologies related to the BIM field are largely settled, and a large number of possible developments have been investigated in both theoretical and procedural terms. Those in the CIM sphere, on the contrary, are still being tested, not only because of their recent implementation. The tools used in BIM are clearly recognizable and widely used, so much so that they have led to shared standards such as interoperability in IFC format. As far as CIM tools are concerned, the most significant experiences have been reported in this paper, but they have yet to mature into shared standards. The relationship between the user and the model is the ideal key to understanding what the developments will be for both architectural and urban scales. Within this dichotomy are the systems of the metaverse that

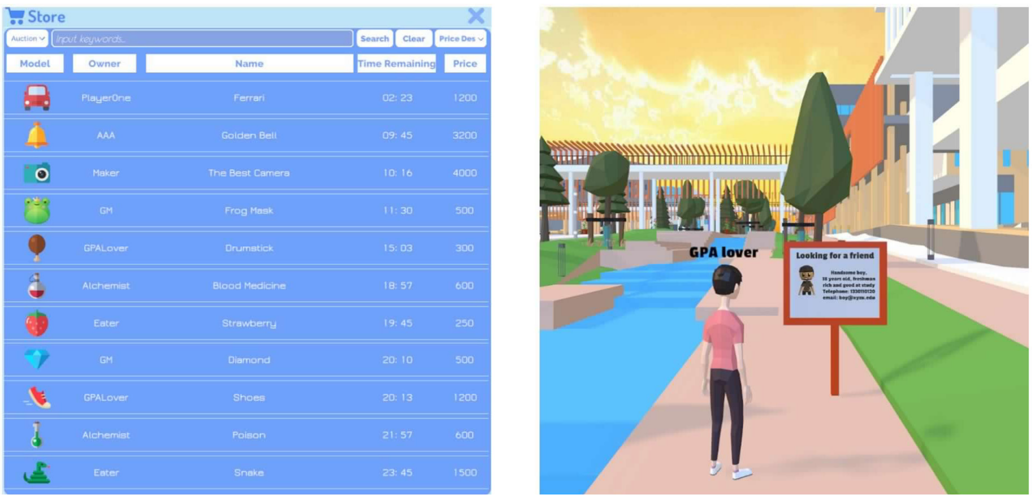

Fig. 8. The Chinese University of Hong Kong, Metaverse representation of provided services to students. Braud et al. 2022.

leverage innovative technologies such as blockchain to manage the enormous masses of data that characterize spaces beyond the individual building. These systems implement the dynamism of human/model interaction that is limited in BIM systems. Simple actions such as opening a door and changing the perception of a space is one of the limitations in this regard. The specificity and precision achieved by BIM systems over a long time of experimentation is, however, still far from being achieved in metaverse ecosystems. The future prospects of the research area of human-model relationships at different scales, in addition to intuitive development of methodologies, need synergistic integration of different technologies, striving to reach the level of standards already achieved for BIM systems.

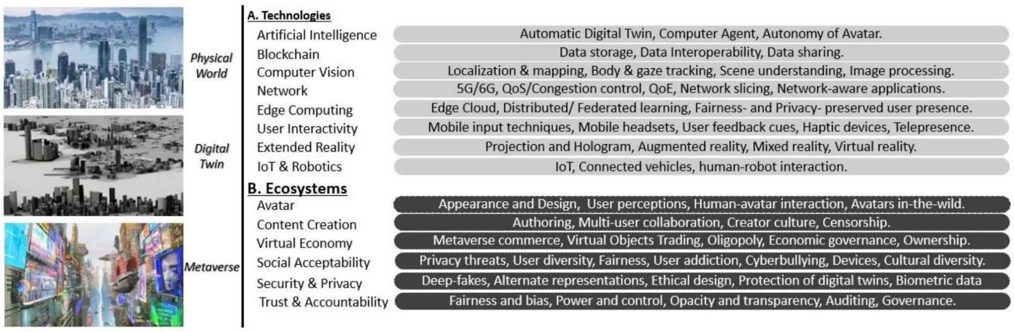

Fig. 3. Connecting the physical world with its digital twins, and further shifting towards the metaverse: (A) the key technologies (e.g., blockchain, computer vision, distributed network, pervasive computing, scene understanding, ubiquitous interfaces), and; (B) considerations in ecosystems, in terms of avatar, content creation, data interoperability, social acceptability, security/privacy, as well as trust/accountability.

Fig. 9. Technologies and ecosystems connecting the physical world, metaverse, and Digital Twin. Khan, Hussain 2020.

Conclusions

In light of the experiments that have been explored in this paper, it is possible to glimpse development directions for digital 3d development fruition platforms. One goal could be the expansion of a digital ecosystem that brings the benefits of digital twin methodologies from the building scale to the urban scale. At present that goal appears distant, but unpredictable developments in the state of the art in this area could bring it significantly closer. Case studies in which what were only utopias a few years ago are actually being put into practice turn out to be extremely interesting. Such cases, when applied on a large scale, will fundamentally change the relationship of sharing between users and models.

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