

New Human Dynamics in the Emerging Metaverse: Towards a Quantum Phygital Approach by Integrating Space and Place

Daniel Sui ✉ 

Department of Geography, Virginia Tech, Blacksburg, VA, USA

Shih-Lung Shaw¹ ✉ 

Department of Geography, University of Tennessee, Knoxville, TN, USA

Abstract

With the convergence of mirror worlds, virtual worlds, lifelogging, and augmented/virtual reality, the emerging metaverse is rapidly becoming a major platform where humans work, shop, entertain themselves, and socialize with others. Human dynamics, which refers to all forms of human activities and interactions, will undergo profound transformations in the coming years with the advent of the metaverse. The new human dynamics will be neither **physical** nor **digital** but a seamless integration of both – **phygital**². The goal of this vision paper is to develop a phygital approach to support human dynamics research in the spirit of GIScience as a convergence. Built on our earlier work in human dynamics research, we argue that the current discussions on human dynamics are conceptually constrained by their physical and digital silos. The new phygital approach we are envisioning aims to transcend the simplistic dichotomy by integrating both space and place perspectives. This paper also draws on basic concepts in quantum physics and earlier discussions on their potential applications in geography and GIScience to espouse a quantum turn in exploring the human dynamics in the emerging metaverse. It explores how concepts, methods, and understandings from quantum physics and emerging quantum computing and communication technologies can be translated into addressing fundamental geographical analyses for this phygital world.

2012 ACM Subject Classification Theory of computation → Quantum information theory; Human-centered computing; Computing methodologies

Keywords and phrases metaverse, human dynamics, phygital, space-place, quantum, GIScience theory

Digital Object Identifier 10.4230/LIPIcs.COSIT.2022.11

Category Vision Paper

Acknowledgements Comments on an earlier draft by Dr. Laurel Miner and research assistance by Dr. Scarlett Jin are gratefully acknowledged. Constructive comments from five anonymous reviewers have also significantly clarified our thinking about the critical issues discussed in our paper. We are solely responsible for any remaining errors.

1 Introduction – The brave new metaverse

When Aldous Huxley penned the historical *Brave New World* back in 1932, he would never have imagined that his brave new world evolved into a brave new metaverse 90 years later in 2022 as evidenced by all the attentions metaverse, which is a hybrid world in which the virtual world based upon digital bits is increasingly linked to the atom-based physical world (<http://www.metaverseroadmap.org>), received by the media, business/industry, and

¹ Corresponding author

² According to Awabot, an Australian agency Momentum invented the term “phygital” and claimed copyright in 2013. A definition and advantages of phygital are provided at Cyberclick.



the research community during the past year. Indeed, those with values different from the prevailing social vision may believe the metaverse will save them from Huxley's Brave New World [8], which some are convinced is already here/inevitable [2].

Human dynamics research, which studies all forms of human activities and interactions in both physical and virtual worlds, currently faces a computing environment that has drastically changed during the past two decades. Instead of the traditional distinction of hardware and software, we have witnessed the emergence of 'everyware' [14]. The future scenario of everyware (sometimes used interchangeably as ubicomp or ambient computing) when people and objects are connected via distributed computing and unconstrained by geographical contexts has arrived faster than expected. Concomitant with the growth of ubicomp/everyware, we are also rapidly entering a new age of the metaverse.

First coined by Neal Stephenson's [28] science fiction novel Snow Crash, metaverse refers to a fictional virtual world where humans, as avatars, interact with each other and software agents in a three-dimensional space that uses the metaphor of the real world. The rapidly evolving metaverse is a result of several converging technologies. According to the metaverse road map report, the browser for engaging this metaverse will be based upon a 3-D Web that brings together the following four technologies:

- Mirror worlds – digital representations of the atom-based physical world, such as Google Earth, Microsoft Virtual Earth, NASA World Winds, ESRI ArcGlobe, USGS National Map, and the massive georeferenced GIS databases developed during the past fifty years, virtual geographical environment (VGE), and a variety of digital twins of the physical world at different scales.
- Virtual worlds – digital extensions of the physical world (e.g., amazon.com) and/or digital representations of imagined worlds (e.g., Second Life, World of Warcraft).
- Lifelogging - the digital capture of information about people and objects in the real or digital worlds (e.g., Twitter, Instagram, YouTube, Facebook/Meta, and TikTok).
- Augmented and virtual reality– sensory overlays of digital information on the real and virtual worlds using a head-up display (HUD) or other mobile/wearable devices such as cell phones or sensors via participatory sensing.

With the rebranding of Facebook as the new Meta [35], 2021 will go down in history as a watershed year for the development of the metaverse. When we now think about GIScience research in general and human dynamics in particular, we cannot separate either of them from the emerging metaverse. Viewed from a metaverse perspective, our discussions of human dynamics within the geospatial community have focused almost exclusively on the perspectives of mirror worlds with growing interests in social media/lifelogging in recent years.

With the convergence of mirror worlds, virtual worlds, lifelogging, and augmented/virtual reality, the emerging metaverse is becoming a platform where humans work, shop, entertain themselves, and socialize with others. Human dynamics will undergo profound transformations in this emerging metaverse. Some scholars also call it synthetic or reality media [6]. The new human dynamics will be neither **physical** nor **digital** but a seamless integration of both – **phygital**. The goal of this vision paper is to develop a phygital approach to support human dynamics research from a broader GIScience perspective. Extending the earlier idea about GIS as media, GIS is increasingly becoming indistinguishable from the reality media created by the emerging metaverse [30, 32].

The rest of this vision paper is organized as follows. After a brief introduction on metaverse in this section, section 2 presents a synoptic overview of the current state of human dynamics research and its limitations. To address these limitations, section 3 outlines key features of a

quantum phygital approach for conducting human dynamics research in the metaverse by integrating space and place. Section 4 further elaborates the theoretical, methodological, and legal/ethical issues of conducting human dynamics and GIScience research in the age of metaverse. Summary and conclusions are contained in the last section.

2 Human Dynamics Research at a Cross Road

Human beings carry out various activities and interactions to meet their needs. According to Maslow's hierarchy of needs, human needs are arranged in hierarchies of predominance that consist of (1) physiological needs (e.g., food, water, sleep), (2) safety needs (e.g., health, employment), (3) love needs (e.g., family, friend), (4) esteem needs (e.g., accomplishment, confidence), and (5) self-actualization needs (e.g., creativity, meaning) [17]. The activities and interactions performed by people collectively become the foundation of the economic, social, cultural, political, and other systems in human societies. In the meantime, the dynamics of these human activities and interactions evolve with the changing environments and technologies over time [25, 23].

Most human activities and interactions were performed in physical space through in-person contacts before the modern technologies made it feasible for us to interact and accomplish certain tasks remotely. As the modern technologies such as personal computers, the internet, and mobile phones became available in the late twentieth century, they enabled an increasing number of human activities and interactions taking place in the so-called virtual space. For example, online shopping and online social networks have replaced some shopping trips and social gatherings in physical space. Mobile phones further relaxed the constraint of staying connected to the network at fixed locations. During the COVID-19 pandemic, teleworking, online education, and many other virtual activities also surged to an unprecedented level. These changes during the recent decades have created an increasingly hybrid physical-virtual world. We now use transportation to move among different places in physical space while we navigate among different places in virtual space via information and communications technology (ICT) [26]. It is important to note that what happens in virtual space often influence and are influenced by what takes place in physical space and vice versa. For example, online orders at amazon.com trigger specific activities and shipments in physical space. It therefore is critical to treat today's world as a hybrid physical-virtual world rather than two independent physical and virtual worlds. In this paper, we use the term human dynamics to cover all forms of human activities and interactions in today's hybrid physical-virtual world (or phygital world).

Batty [4] argues that "the future subject matter and method of geography will be very different as place and space and time itself become virtual in an age where the digital permeates all human activity" (p.351). There is no doubt that we now live in a phygital world envisioned by Michael Batty twenty-five years ago. Taylor [34] also discusses emerging geographies of virtual worlds enabled by virtual reality (VR) technology. Nevertheless, most conventional geographic information systems (GIS) methods have focused on human dynamics in physical space with the following assumptions: (1) objectivism which assumes that objects exist independent of the subjects who observe them, (2) materialism which assumes that the elementary units of reality are physical objects, (3) reductionism which assumes that larger objects can be reduced to smaller ones, (4) determinism which assumes that objects behave in law-like ways; and (5) mechanism which assumes that causation is mechanical and local. Even when virtual activities are considered in a study [3], the above assumptions often are implied in the study by treating human dynamics in physical space and

human dynamics in virtual space as two independent and parallel worlds. Some studies have attempted to associate human activities in virtual space with human activities in physical space through data such as geotagged tweets [27]. However, the location where a tweet is sent may have nothing to do with the content of a tweet which could generate misleading analysis results. As we move into a hybrid phygital world, it is imperative to pursue human dynamics research with approaches beyond the limits set by the above assumptions and develop approaches that can better integrate human dynamics in a hybrid phygital world.

Taking online shopping at amazon.com as an example, there exist various challenges that we must address. For example, what is the location of amazon.com? How should we represent amazon.com in a GIS environment? In practice, we could use the location of Amazon headquarters office to represent its location in GIS. However, this location may be irrelevant to most transactions at amazon.com. An alternative is to use the street address of the specific vendor's location to represent where an item will be shipped out. But, the vendor may have multiple warehouses from which the ordered item could be shipped. In reality, most people who place orders at amazon.com do not care much about the vendor's location. Instead, they may pay more attention to online reviews or delivery date. In this case, the identity of amazon.com and/or the vendor in virtual space is more critical than their locations in physical space when users place an order at amazon.com. Such human dynamics can be better handled as a relational space, which represents the relations among different entities such as a social network graph, than as an absolute space that assumes an infinite and immovable space which exists independent of other things [24]. Furthermore, online reviews, comments made by friends, and our own experiences with different vendors and online shopping websites also influence our perceptions and attitudes in mental space which in turn will affect our behaviors. These examples illustrate why we need to develop a new framework for studying human dynamics in today's hybrid phygital world. The recent development of Amazon Go and Amazon Fresh, built upon a combination of their "just walk-out" technologies, is the latest quintessential example of the phygital shopping we all will soon experience in the metaverse.

3 Human dynamics and the emerging metaverse: Towards a quantum phygital approach by integrating space and place

3.1 Human dynamics will be increasingly phygital

The new buzzword phygital went viral during the past two years since the beginning of the global pandemic. Technically speaking, "phygital" refers to the seamless integration of both physical and digital universes that captures the essential features of both virtual world and physical world so that we can maximize and optimize our experiences in both.

Operationally, a phygital strategy is closely related to other business strategies such as immersive marketing, omnichannel, or O2O (online-to-offline), but with the accelerated maturing and advances in virtual reality, augmented reality, social media, digital twins and other mirror world technologies, the emerging metaverse has made the following three characteristics a reality for the phygital world: (1) Immediacy: It works to ensure things happen at an exact moment in time; (2) Immersion: The user is an integral part of the experience; and (3) Interaction: Communication is constant and activates the more physical and emotional part of the experience.

There have been many successful phygital implementation examples lately, such as Amazon's Go store, Pokemon Go game, Magik Book, smart tourism, and the emerging phygital banking. This trend is certainly not confined to business and retail, but is also

rapidly diffusing to other sectors such as the government operations, higher education, worship activities, and other non-profit operations. This is indeed a phygital age and this neologism captures a pivotal moment in human history. For the geospatial world, we have become increasingly phygital as well since the early 1960s as we gradually move away from the world of analog paper maps to digital geospatial information. From the early adoption of Global Positioning System (GPS) technologies in civilian applications to the growing popularity of Uber and more broadly to the emerging spatial computing paradigm, what we are dealing with is neither physical nor digital, but increasingly phygital. Concomitantly with this transformation, we are not just dealing with physical/absolute space but also a variety of other spaces and places. This mandates that we need to broaden our conceptual framework to move beyond the Newtonian physical world we are accustomed to in order to better understand the new reality we are in.

3.2 Integrating space and place to understand phygital human dynamics

Space, place, and human are three fundamental elements in geography. Geographers traditionally focus on the spaces that are relevant to human life and the places that are created by human activities. There exist different approaches to conceptualizing space and place. In cartography and GIS, space is often represented according to Newton's concept of *absolute space* and operationalized through Cartesian coordinates and Euclidean geometry. Under this representation, objects can be placed and events can take place at various locations in an empty and objective absolute space. The concept of absolute space can be transformed into the concept of *relative space* by relaxing the assumption of a fixed origin point in absolute space. If we allow the origin point to move with the observer, it becomes a relative space that represents the spatial separation between an observer and other objects based on their relative locations.

We also can create schematic maps that focus on the connections among a set of places such as a map showing the subway network in London, United Kingdom. On a schematic map, the actual locations of network nodes and network links in physical space are not critical as far as the network links represent the correct topological connections among the network nodes. Such schematic maps are examples of representing the relationships in a *relational space*. Furthermore, we can create mental maps to represent maps in human mind that reflect our understanding of the world around us based on a mixture of objective observations and subject perceptions. Locations on a mental map are usually distorted from their physical locations in absolute space. Mental maps, therefore, are examples of representing objects in a mental space.

In addition to the concepts of space, there also exist different concepts of place. Tuan [36] indicates that human beings create meanings to an area in space that becomes a place. Places, therefore, are social constructs that can have different meanings to different people and can evolve over time [22]. Agnew [1] further suggests that the concept of place covers three different dimensions, which are location, locale, and sense of place. When a place is viewed as a location, it is considered as a site in space where an object or an event is located. In this case, we can use (x,y,z) coordinates to define a location in absolute space. When a place is viewed as a locale, it is considered as a setting where activities take place. Locale, therefore, refers to the physical, socioeconomic, and cultural context within which activities occur. The concept of relative space that focuses on the surrounding environments around the observer fits well with the concept of locale. When a place is viewed as sense of place, it is associated with identification with a place such as a sense of belonging to a place. Such human subjective perceptions or attachments to a particular location or locale can be

associated with the concept of mental space. Furthermore, place identity is the most critical element under the concept of relational space to identify the relationships among different entities.

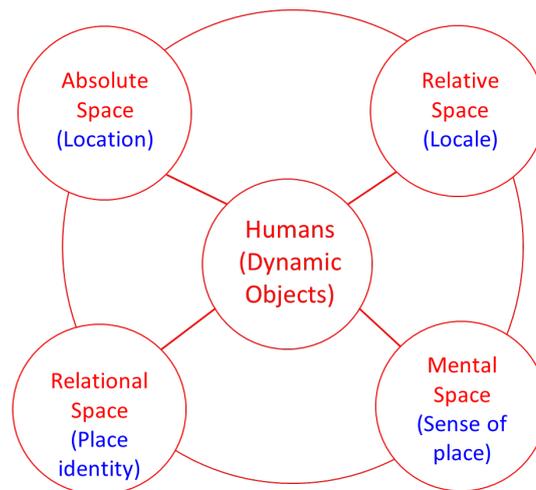
Based on the concepts of absolute space, relative space, relational space, and mental space as well as the concepts of location, locale, place identity, and sense of place, Shaw and Sui [24] propose a space-place (or splatial) framework for a better understanding of human dynamics in a hybrid phygital world (Figure 1). This framework puts humans at the center since human dynamics is created by human activities and interactions to fulfill various needs. In addition, humans are not static objects at fixed locations. They navigate among different places in both physical space and virtual space to carry out different activities and interactions. Humans therefore are treated as dynamic objects in this framework. Humans, who have experienced a “digitization” of every facet in their lives, have discovered new ways to fulfill their needs. Just as Amazon digitized written knowledge with eBooks and YouTube digitized verbal/visual knowledge, blockchain now has digitized property rights for transactions in virtual space. Those who recognize and believe this shift are willing to give this new world an ontological status, thus investing heavily into entities in this new virtual space [11].

The space-place couple of *absolute space/location* in this framework addresses questions such as “Where are the different objects?” that have been implemented in conventional GIS and many other spatial analysis methods. The space-place couple of *relative space/locale* addresses questions such as “What is around us?” that places an emphasis on the context and surrounding environments. The space-place couple of *relational space/place identity* addresses questions such as “What is related to us?” that focuses on the connections among different people and/or entities. Finally, the space-place couple of *mental space/sense of place* addresses questions such as “What do people have in mind?” that refers to the cognitive and mental aspects of human dynamics. The lines connecting these four space-place couples and humans in this framework indicate that they are not independent of each other. Instead, a particular human activity or interaction could be represented by multiple space-place couples that are linked with each other. This framework, therefore, offers a robust yet flexible design to integrate human dynamics in a hybrid phygital world according to different application needs. For example, if an application only requires representations of the absolute space/location couple in physical space and the relational space/place identity couple in virtual space, it does not need to create representations of the relative space/locale couple or the mental space/sense of place couple.

3.3 Rethinking the phygital human dynamics in the metaverse: Towards a quantum leap

If indeed we need to seamlessly integrate space and place to better capture the phygital process that defines the new human dynamics in the metaverse as we move into a post-pandemic world, the assumptions based upon the Newtonian classic world view seem to be unwarranted. Instead we need to reframe human dynamics research by espousing an explicit quantum turn [33].

Quantum theory, initially developed in the early twentieth century, disrupts all the five assumptions in the traditional research outlined in section 2, reflecting the world view of classic Newtonian physics. Viewed from quantum perspectives at the sub-atomic level, systems are not independent of observers; physical objects dissolve into ghost-like processes; and the whole cannot be reduced to parts. Quantum physics recognizes that elements exist as both waves and particles, and an object’s state is a wave function that collapses upon measurement. Furthermore, the world does not behave deterministically, and causation is non-local – a phenomenon also known as quantum entanglement.



■ **Figure 1** A space-place (spatial) framework for human dynamics research (Adapted from [24]).

Importantly, these findings do not necessarily invalidate the classical worldview at the macro level, since quantum states normally ‘decohere’ into classical ones above the molecular level, which is why the everyday world appears to us as conforming to the classical worldview. Decoherence has been a barrier to developing a unified quantum theory encompassing both micro and macro levels, and is a fundamental obstacle to the quantum consciousness hypothesis in particular [39]. Nevertheless, at the nano-level, the quantum revolution has decisively overturned the claim of the classical worldview to provide a complete description of reality.

Inspired by Zohar’s [40] ground-breaking work, we find the following four quantum concepts are particularly useful when we try to reframe the human dynamics research that is increasingly phygital in the emerging metaverse, often requiring integration of multiple spaces and places to capture their complexity.

1. *Complementarity (holism)*: This refers to the tenet that a complete knowledge of phenomena on atomic dimensions requires a description of both wave and particle properties, the ‘wave-particle duality’. Similarly, human dynamics are no longer either physical or digital but both. The portmanteau word phygital captures this new duality of human dynamics.
2. *Entanglement (non-locality)*: Entanglement in quantum physics refers to the phenomenon that measuring one particle immediately alters the properties of the other, even when they are physically separated. Entanglement, also described as ‘spooky action at a distance’ by skeptical Einstein and his colleagues [12], negates the idea of local realism, in which every event has an immediate cause. The new human dynamics in the metaverse are deeply entangled, at least metaphorically (if not physically), at the global scale as everybody is connected through the Internet with the information exchange instantly.
3. *Superposition (potentiality)*: Much like waves in classical physics, any two (or more) quantum states can be added together (“superposed”) and the result will be another valid quantum state; and conversely, every quantum state can be represented as a sum of two or more other distinct states. Unlike the macro physical world, quantum physics reveals that the nature or the behavior of matter at the sub-atomic scale can be actually in all possible states simultaneously [16]. We do not know what the state of any object is as long as we do not look to check. The act of measurement itself causes the object to be

limited to single possibility. The concept of superposition thus disrupts our traditional separation of object from subject. Apparently, the phygital human dynamics in the metaverse are always in a state of high potentiality, with multiple states superimposed with one another until measurement/observation is taking place.

4. *Uncertainty (non-determinism)*: The uncertainty principle asserts that our ability to completely measure of quantum states is fundamentally limited. Knowledge about two dimensions is complementary, and the more accurately we measure one property (e.g., particle speed) and less likely we can measure accurately another (e.g., particle position). The quantum uncertainty is not a limitation in measurement technology or experimental sophistication, but a fundamental attribute of the mathematical formalism that underlies quantum theory and has been supported by a century of experimentation. With the growing misinformation, anonymity online. and the rise of bots, we should be more mindful about the non-deterministic aspect of human dynamics in the metaverse. The only certainty about the phygital world is its uncertainty.

Drawing from the concept of superposition, Bittner [5] proposed a quantum theory of geographic fields that allows for the possibility of representing multiple incompatible states simultaneously at a given point of the geographic field. This quantum theory of geographic fields provides a new level of synthesis and understanding of indeterminacy and ontological vagueness in the geographic world. Indeed a quantum-inspired ontology (based upon entanglement and superposition) and epistemology (based upon the inseparability of the observer and the observed) would provide us a more robust conceptual framework to implement the spatial framework to better understand human dynamics in the phygital metaverse.

4 Further Discussions

We hope that the broad-brush road map we charted above for exploring the new human dynamics in the emerging metaverse will entice more followers in the GIScience community to hit the road to start their journey in the phygital world. We should point out that multiple of, if not all, the key elements of the metaverse have been discussed in the literature since the late 1990s [10, 13, 30, 32]. What is new and exciting is the accelerated convergence of these diverse technologies and theoretical frameworks. There are many fundamental issues that need to be addressed for the quantum approach to studying human dynamics in the phygital metaverse. We have aimed to connect the dots in this paper. The geospatial community needs to make concerted efforts to further investigate the theoretical/philosophical, methodological/technical, and legal/ethical issues related to the metaverse. It is beyond the scope and page limit of this paper to cover these issues in detail, but suffice it here we can present a synoptic overview for further discussion.

4.1 Theoretical and Philosophical Issues

We would like to place the exploration of phygital human dynamics in the metaverse in a broad theoretical/philosophical context. Even before metaverse became trendy, Oxford philosopher Nick Bostrom [7] had made the simulation argument, hypothesizing that we humans may be increasingly living in a matrix-like simulation. According to this argument, it is quite possible that multiple versions of ourselves exist in parallel universes living out their lives in different spaces and timelines. Virk [37] further expanded this argument - if we are indeed living in a simulated universe composed of information that is rendered around us, then many

of the complexities and baffling characteristics of our reality start to make more sense. In particular, Virk [37] argued that the two most popular interpretations of quantum mechanics, the Copenhagen Interpretation and the Many Worlds interpretation, which are thought to be mutually exclusive, can be unified in an information-based framework. Quantum computing, in theory, can enable us to simulate complex phenomena in parallel, allowing the simulation to explore many realities at once to find the most “optimum” path forward. This could explain not only the enigmatic Mandela Effect, but more importantly, provides us with a new understanding of time and space, consistent with the splatial framework we discussed earlier.

Is the simulation argument just another metaphor invoked by scholars based upon the dominating technologies of our time as we did in the past [31], or is it really a very profound theory that is physically and literally true that can help GIScientists better address the ontological and epistemological deficiencies critics leveled against GIS earlier [29]?

4.2 Methodological and Technical Issues

Methodologically, the use of ‘quantum-like’ mathematical and statistical models to study probabilistic dynamical systems has increasingly become popular. Working along this line will surely have implications for exploring the new human dynamics in the metaverse of a phygital world. In the emerging quantum social science literature, Haven and Khrennikov [15], along with Orrell [20, 21] and Project Q, have already demonstrated the potential applications of a quantum approach in studying a wide range of issues in economics, finance, psychology, sociology, and other domains of inquiry with the help of formal models and concepts used in quantum physics. In particular, recent advances in quantum cognition and psychological modeling [38, 9] may be the most relevant and even directly applicable for studying human dynamics in the metaverse of a phygital world. Quantum decision-making recognizes that judgments and decisions are influenced by context, and that entangled systems cannot, in theory, be modeled as separate systems. It draws attention to quantum theory as a statistical theory, recognizing that the interference of probabilities is a basic statistical feature of quantum theory. Quantum formalisms are merely considered a more effective way of processing incomplete information and accounting for the interference of probabilities in macroscopic quantum systems.

By exploiting collective properties of quantum states, such as superposition and entanglement, to perform computation, quantum computers have been proven to be able to solve certain computational problems substantially faster than classical computers. The demands for computing power for data processing related to human dynamics in the metaverse of a phygital world will increase exponentially. The goal of quantum supremacy or quantum advantage is to demonstrate that a programmable quantum device can solve a problem that no classical computer can solve in any feasible amount of time (irrespective of the usefulness of the problem). As of now, there are generally four ways to build quantum computers (<https://spectrum.ieee.org/4-ways-to-make-bigger-quantum-computers>), but fundamental to all is the quantum bit (qubit or qbit), which provides an exponential advantage over classical computers that are based upon digital bits in binary states of either 0 or 1. Furthermore, quantum computers are the most promising to address issues related to communication and security in the metaverse, with improvements unmatched by classical computers. Most if not all current blockchain code is reliant on SHA-256 hash functions, which is secure enough for classical computing. But preliminary work showing the power of quantum computing to break a SHA-256 code has further elevated the importance and urgency of embracing quantum computing into the future of the metaverse. Indeed, the potential impacts of quantum supremacy for human dynamics in the metaverse of a phygital world cannot be overestimated.

4.3 Legal and Ethical Issues

Although still at an early stage, core metaverse technologies have demonstrated that we are enabled to travel across space and time at an unprecedented level of granularity and a high degree of fidelity. Concomitantly, metaverse has also transported us onto a new uncharted legal and ethical territory that deserves our attention. Due to enormous financial potentials, there are mounting intellectual property issues looming, especially related to patents, contracts, and non-fungible tokens (NFTs) in the metaverse. The emergence of the metaverse challenges the core propositions in our current patent law, i.e., what is patentable and what is not? As for the content in the metaverse, most of the claims will fall into three categories - copyright, trademark, and right of publicity. Legal boundaries are currently not clearly defined regarding what can and can't be included in the metaverse content. There are also liability claims of users against metaverse companies and users against other users in the emerging metaverse.

More than simply a technological marvel and advance, we must regard the emerging metaverse as one of the greatest social experiments humanity has ever taken throughout history, one that merges our physical and digital identities and our physical and virtual presence. This phygital world allows us to create and recreate ourselves as many times as we choose across multiple spaces and places in both physical space and virtual space. Our avatars will not be limited by space and time constraints of our own physical bodies.

So, in addition to the legal challenges, our new phygital persona in metaverse also raises a profound set of ethical questions related to privacy, safety, equity, and agency. It remains to be seen how all the stakeholders can work together to create spaces and places for everyone to thrive in the metaverse, including the GIS community which must deal with the new concepts of space, place, time, and human dynamics in the metaverse. Additionally, we have to have strong identity and security solutions for the convergence of digital and physical worlds to protect the creators, the brands, and the consumers.

Scientific discourses are not a separate sphere of society. They are part of social cultures. Scientific discourses contribute to shaping ontologies and causal stories. Ontological imaginaries shape our political and research practices and how we validate them. In an entangled quantum world, we may also be able to bring about big changes through small local actions (micropolitics). Ethically and politically, quantum onto-epistemologies raise the bar for adjudicating ethical choices, and at the same time, open up possibilities for further actions and engagement. With its non-local, non-deterministic, and participatory approach to social change, the quantum perspective advocated in this paper sheds a brighter light on the new ethics in the phygital age. By taking non-local, hidden, and subjective factors seriously and explicitly, quantum ethics perhaps can guide our social practices to address complex issues facing humanity today, such as increasing global polarization, growing economic disparity, and worsening global environmental change. Indeed, uninformed populism and nationalist approaches go against an entangled worldview as espoused by the quantum turn. O'Brien [18] lays out a road map on how the quantum perspective could help us better cope with the challenges posed by global climate change through meaningful social transformation.

5 Concluding Remarks: GIScience as a convergence science

GIScience in general and human dynamics research in particular have undergone major changes during the past three decades, and yet nothing is as profound and far-reaching as we are going through right now. With the maturing of metaverse technologies, quantum

computing, AI/machine learning, and blockchains, GIScience and human dynamics research are on the cusp of another major paradigm shift that calls for new theories, methodologies, and ethics for us to better deal with the brave new phygital world we increasingly live in.

In the spirit of accelerating convergence research, this vision paper has tried to present a unified spatial framework to better understand the phygital human dynamics by integrating previous conceptualization of multiple spaces and places. Moving away from the absolute conceptualization of space and place as defined by Newtonian physics, the spatial framework embodies the core concepts of quantum physics. We hope this vision paper has charted new territory for further exploration along theoretical, methodological, and ethical fronts. More than ever, GIScience and human dynamics research need to take a convergence approach instead of the traditional siloed approach.

According to the U.S. National Academy of Sciences [19], convergence research must have two primary characteristics:

- **Transdisciplinarity:** As experts from different disciplines pursue common research challenges, their knowledge, theories, methods, data, research communities, and languages become increasingly intermingled or integrated. New frameworks, paradigms, or even disciplines can form sustained interactions across multiple communities.
- **Stakeholder synergy:** In order to have broader impacts, research should be conducted by drawing together academic researchers, policymakers, and industry partners. Convergence research is generally inspired by the need to address a specific challenge or opportunity, whether it arises from deep scientific questions or pressing societal needs.

As shown throughout this paper, no single discipline can actually claim exclusive ownership on addressing any challenges or issues outlined in this paper. Convergence GIScience and human dynamics research entails a transdisciplinary approach to seamlessly integrate theories, methods, and data from multiple disciplines. Moreover, convergence further mandates stakeholder synergy in order to create broader public impacts of the research we are conducting. Stakeholder synergy – the integration of academia, industry, and government – is critically important for the success of GIScience and human dynamics research. By default, seeking stakeholder synergy automatically mandates the synthesis of creative works by multiple teams with diverse backgrounds. Apparently, a team science approach is needed to develop GIScience and human dynamics research in the context of stakeholder synergy, which mandates academics to move beyond their comfort zone to address pressing issues facing society today. Of course, we are mindful of the future of government in light of the accelerated adoption of blockchain technology. Bitcoin (or cryptocurrency more generally) was created in the wake of the global financial crisis of 2008 because of a growing, and still quite prevalent, distrust of government, authorities/institutions, and big corporations. A key attribute of the cryptocurrency is its libertarian ideal of decentralized, permissionless, self-governing operation, not controlled by a central authority.

Over the past two decades, there has been an emerging emphasis on scientifically addressing multi-factorial problems, such as climate change, fighting global terrorism, the rise of infectious/chronic diseases, the health impacts of social stratification, and growing concerns of social disparity. This has contributed to a surge of interest and investment in team science. Increasingly, scientists across many disciplines and settings are engaging in team-based research initiatives. These include small and large teams, uni- and multi-disciplinary groups, and efforts that engage multiple stakeholders such as scientists, community members, and policymakers. Since the first road map for our phygital future in the metaverse was articulated by a team of industry leaders, it is even more critical that academic GIScience researchers should aggressively seek stakeholder synergy for our future endeavors.

References

- 1 John A. Agnew. *Space and place*, chapter The SAGE Handbook of Geographical Knowledge, pages 316–330. SAGE Publications, Los Angeles, 2011.
- 2 Tom Arant. *Welcome to Our Real Matrix*. Thomas F. Arant, 2021. URL: https://www.ebook.de/de/product/41008107/tom_arant_welcome_to_our_real_matrix.html.
- 3 Albert-László Barabási. The origin of bursts and heavy tails in human dynamics. *Nature*, 435(7039):207–211, 2005. doi:10.1038/nature03459.
- 4 Michael Batty. Virtual geography. *Futures*, 29(4-5):337–352, 1997. doi:10.1016/S0016-3287(97)00018-9.
- 5 Thomas Bittner. Towards a Quantum Theory of Geographic Fields. In Eliseo Clementini, Maureen Donnelly, May Yuan, Christian Kray, Paolo Fogliaroni, and Andrea Ballatore, editors, *13th International Conference on Spatial Information Theory (COSIT 2017)*, volume 86 of *Leibniz International Proceedings in Informatics (LIPIcs)*, pages 5:1–5:14, Dagstuhl, Germany, 2017. Schloss Dagstuhl–Leibniz-Zentrum fuer Informatik. doi:10.4230/LIPIcs.COSIT.2017.5.
- 6 Jay David Bolter, Maria Engberg, and Blair MacIntyre. *Reality Media*. The MIT Press, 2021. doi:10.7551/mitpress/11708.001.0001.
- 7 Nick Bostrom. The simulation argument: Why the probability that you are living in a matrix is quite high. <https://www.simulation-argument.com/matrix.html>, 2013. Accessed: 2022-1-23. URL: <https://www.simulation-argument.com/matrix.html>.
- 8 Andrew Bosworth and Nick Clegg. Building the metaverse responsibly. <https://about.fb.com/news/2021/09/building-the-metaverse-responsibly/>, 2021. Accessed: 2022-1-23.
- 9 Jerome R. Busemeyer and Zheng Wang. Quantum cognition: Key issues and discussion. *Topics in Cognitive Science*, 6(1):43–46, 2014. doi:10.1111/tops.12074.
- 10 Mike Crang, Phil Crang, and Jon May. *Virtual geographies*. Routledge London, 1999.
- 11 Christopher DiLella and Andrea Day. Investors are paying millions for virtual land in the metaverse, 2022. Accessed: 2022-1-23. URL: <https://www.cnbc.com/2022/01/12/investors-are-paying-millions-for-virtual-land-in-the-metaverse.html>.
- 12 A. Einstein, B. Podolsky, and N. Rosen. Can quantum-mechanical description of physical reality be considered complete? *Physical Review*, 47(10):777–780, 1935. doi:10.1103/physrev.47.777.
- 13 Peter Fisher and David Unwin. *Virtual reality in geography*. CRC Press, 2001.
- 14 Adam Greenfield. *Everyware: The dawning age of ubiquitous computing*. New Riders, 2006.
- 15 Emmanuel Haven and Andrei Khrennikov, editors. *The Palgrave handbook of quantum models in social science*. Springer, 2017.
- 16 Julia Layton. Scientists prove Schrodinger’s cat can be in two places at once. <https://science.howstuffworks.com/science-vs-myth/everyday-myths/scientists-prove-schrodingers-cat-can-be-two-places-once.htm>, 2021. Accessed: 2022-1-23.
- 17 Abraham H Maslow. *A dynamic theory of human motivation*, chapter Understanding Human Motivation, pages 26–47. Howard Allen Publishers, Cleveland, OH, 1958.
- 18 Karen O’Brien. *You Matter More Than You Think: Quantum Social Change for a Thriving World*. cChange Press, Oslo, Norway, 2021. URL: https://www.ebook.de/de/product/41827474/karen_o_brien_you_matter_more_than_you_think_quantum_social_change_for_a_thriving_world.html.
- 19 National Academies of Sciences (NAS). *Convergence: Facilitating Transdisciplinary Integration of Life Sciences, Physical Sciences, Engineering, and Beyond*. National Academies Press, Washington D.C., 2014.
- 20 David Orrell. *Economyths: 11 Ways Economics Gets It Wrong*. Icon Books Ltd, July 2017. URL: https://www.ebook.de/de/product/28540206/david_orrell_economyths.html.
- 21 David Orrell. *Quantum Economics: the new science of money*. Icon Books Ltd, London, 2018.

- 22 Stéphane Roche. Geographic information science II. *Progress in Human Geography*, 40(4):565–573, 2015. doi:10.1177/0309132515586296.
- 23 Shih-Lung Shaw and Daniel Sui. *Human Dynamics Research in Smart and Connected Communities*. Springer International Publishing AG, Cham, Switzerland, 2018.
- 24 Shih-Lung Shaw and Daniel Sui. Understanding the new human dynamics in smart spaces and places: Toward a spatial framework. *Annals of the American Association of Geographers*, 110(2):339–348, 2019. doi:10.1080/24694452.2019.1631145.
- 25 Shih-Lung Shaw, Ming-Hsiang Tsou, and Xinyue Ye. Editorial: human dynamics in the mobile and big data era. *International Journal of Geographical Information Science*, 30(9):1687–1693, 2016. doi:10.1080/13658816.2016.1164317.
- 26 Shih-Lung Shaw and Hongbo Yu. A GIS-based time-geographic approach of studying individual activities and interactions in a hybrid physical–virtual space. *Journal of Transport Geography*, 17(2):141–149, 2009. doi:10.1016/j.jtrangeo.2008.11.012.
- 27 Luke Sloan and Jeffrey Morgan. Who tweets with their location? understanding the relationship between demographic characteristics and the use of geoservices and geotagging on twitter. *PLOS ONE*, 10(11):e0142209, 2015. doi:10.1371/journal.pone.0142209.
- 28 Neal Stephenson. *Snow Crash*. Bantam Books, New York, 1992.
- 29 Daniel Z. Sui. Gis and urban studies: Positivism, post-positivism, and beyond. *Urban Geography*, 15(3):258–278, 1994. doi:10.2747/0272-3638.15.3.258.
- 30 Daniel Z. Sui. Cybergis: A perspective from the emerging metaverse. In Shaowen Wang, Nancy R. Wilkins-Diehr, and Timothy L. Nyerges, editors, *Proceedings of the NSF CyberGIS Workshop*. University Consortium of Geographic Information Science (UCGIS), 2010.
- 31 Daniel Z. Sui. *Rethinking progress in urban modeling: Models, metaphors, and meaning*, chapter Urban Remote Sensing: Monitoring, synthesis, and modeling in the urban environment, pages 371–382. Wiley, New York, 2010.
- 32 Daniel Z. Sui. From the mirror worlds to everywhere in the metaverse: Or what is special about spatial (computing)? In *Proceedings of the Spatial Computing Workshop*. The U.S. National Academies of Science, 2012.
- 33 Daniel Z. Sui. *The quantum turn for geospatial technologies and society*, chapter The Routledge Handbook of Geospatial Technologies and Society. Routledge, London, 2021.
- 34 Jonathan Taylor. The emerging geographies of virtual worlds. *Geographical Review*, 87(2):172–192, 2010. doi:10.1111/j.1931-0846.1997.tb00070.x.
- 35 TechFacebook. Connect 2021: Our vision for the metaverse, 2021. Accessed: 2022-1-23. URL: <https://tech.fb.com/connect-2021-our-vision-for-the-metaverse/>.
- 36 Yi-Fu Tuan. *Space and Place: The Perspective of Experience*. University of Minnesota Press, Minneapolis, 1977.
- 37 Rizwan Virk. *The Simulated Multiverse: An MIT Computer Scientist Explores Parallel Universes, The Simulation Hypothesis, Quantum Computing and the Mandela Effect*. Bayview Books, Mountainview, CA, 2021.
- 38 Zheng Wang, Jerome R. Busemeyer, Harald Atmanspacher, and Emmanuel M. Pothos. The potential of using quantum theory to build models of cognition. *Topics in Cognitive Science*, 2013. doi:10.1111/tops.12043.
- 39 Alexander Wendt. *Quantum Mind and Social Science*. Cambridge University Press, Cambridge, 2015.
- 40 Danah Zohar. *The quantum society: mind, physics and a new social vision*. Morrow, New York, 1994.