Philosophy and methods for the seamless exploration of spatial scales

Taylor Hinchliffe

Introductory statement

This project and writing aims to discuss the philosophy and importance of seamlessly exploring different spatial magnitudes, and describes a variety of methods, spanning digital art to machine learning, to help create such experiences.

Part I: Philosophy

Hidden universes

Ever since the linguistic conceptualization and sharing of the concept "atom" in ancient Greece, and the hybridization and blossoming of natural philosophy into modern science, humankind steadily and then rapidly has come to realize that the arrangement of matter into different architectures varies wildly depending on the system and spatial scale under consideration. Improving our understanding of the arrangement of matter into architectures that are too small or too large to see and experience directly improves our understanding of the objects of experience, of self, of environment and place in the universe. By understanding how matter is arranged at different spatial scales, we may begin to combine and extend this understanding beyond our sensory thresholds, enriching our experiences with increased detail and 'resolution'. This in turn adds detail to our attempts at answering who and what we are, what we are doing, and what should we do. Likewise, when the arrangement of matter at two different spatial scales has a continuous connection between the two systems, such as looking at the bricks of a home, as well as considering the arrangement of molecules within a single brick, *one system architecture will always fall 'inside' the other*. Honing our intuition of how, for example, one system architecture of many arranged parts, when increasing spatial magnitude, itself becomes just one part of many of a greater system, helps ensure we do not lose sight of the forest for the trees, or vice versa, because although an individual tree and an entire forest look and act quite differently, an understanding of both is required to truly understand either. Thus our understanding is heavily based on understanding arrangements, whether of structures or behaviors or both.

"Now the essential value in this conception is, that it enables us to look, upon these different organs of a plant as modifications of one and the same organ—it enables us to think about the different varieties of the flower head as modifications of one single plant form. We can trace correspondences between them, and are led to possible explanations of their growth. And all this is done by getting rid of pistil and stamen as separate entities, and looking on them as leaves, and their parts due to different arrangement of the leaf structure. We have reduced these diverse objects to a common element, we have found the unit by whose arrangements the whole is produced. And in this department of thought, as also to take another instance, in chemistry, to understand is practically this: we find units (leaves or atoms) combinations of which account for the results which we see. *Thus we see that that which the mind essentially apprehends is arrangement*." —Charles Hinton, *A New Era of Thought* (1)

Extending perspectives

Anytime a system is placed under consideration in the experience and mind of the individual, it is inherently constrained to a 'frame' of reference and perspective, for the experience of conceptualizing a system, if taken itself as a system, will always be tethered to systems that lie outside or beyond it, or are too deeply 'within' it to be experienced directly. Heightening awareness of our perspectives and frame of reference as we conceptually transverse differing spatial scales helps remind us of the powerful mental tools we possess but may not always use. As said again by Charles Hinton in *A New Era of Thought* (1), "…it is by means of space that we apprehend what is. Space is the instrument of the mind." Emphasizing some of the ways in which we may use the direct experience of the mind to move through space in ways in which our body cannot helps further define space, or the process of transversing space, as an instrument of the mind, so that this instrument can be used to advance and enrich our understanding of experience. Some of the most intuitive methods in which the mind may conceptually move experience through space is to take the current perspective and 'zoom in' or 'zoom out', or rotate or translocate the perspective. One may also attempt to conceptually ‘expand’ the perspective itself so as to literally provide more room for more details. Likewise, another method of transversing space, or in this case, examining the behavior of space, is by transversing time. One of the simplest and most intuitive methods of doing so is simply to understand how space changes, and then mentally play, pause, fast-forward or rewind the ‘unfolding’ or ‘folding up’ of these changes.

Peering through technology

Technologies have provided us with windows for which to peer at or into systems at levels of detail that the mind may miss or be incapable of generating itself, and yet technologies are still considerably behind the capability of the mind to seamlessly explore arrangements of matter in space as brought to order by knowledge and experience. Still, many pieces of technology and information are starting to emerge that, when arranged properly, will help externalize the mind’s seamless exploration of space. The end goal of this thus seems to be an improved version of the same thing — the externalization and betterment of the process of navigating space and time as an instrument of both the mind and technology. For this to occur, moving through space with the help of external technological windows superimposed over our experiences should be similar to the seamlessness of moving through space with the mind alone. This means that our technological windows should allow us to smoothly zoom in and out, rotate or translocate the perspective, and eventually, play, pause and rewind or fast-forward time. The writing below primarily focuses on technological and artistic methods for zooming in and out of space, and includes the navigation of time as a future direction.

Reconnecting our understanding of arrangements of matter at different scales

For the above to occur, embedded somewhere within the technologies we interact with, or within the technologies our technologies interact with, *must be simulations of the arrangement of matter at different spatial scales*. These simulations, or the data required to create these simulations, are dispersed far and wide throughout both physical and digital collections of knowledge, spanning millions of scientific publications, to databases of molecular structures or atomic behaviors, or even historical documents. However, it seems to be the natural tendency of mankind to arrange information into higher levels of order and organization, which will be crucial if we are to externalize our mind's seamless exploration of space, because the seamless exploration of space requires each incoming perspective to be properly tethered to the outgoing perspective at the mathematically correct size magnitude. And even before this can occur, great effort is required to correctly arrange matter in the first place. As one example, recent work by the team of Dr. David Goodsell helps to illustrate how many sources of information must be technologically integrated to properly arrange matter — in this case, to properly create a hypothetical arrangement of the molecules (as well as the atoms composing each molecule) composing a single, particularly small bacterium as shown in Figure 1 (2). This example leads us to part two of this writing, which delves deeper into the technologies and methods that may be arranged to help externalize the exploration of space.

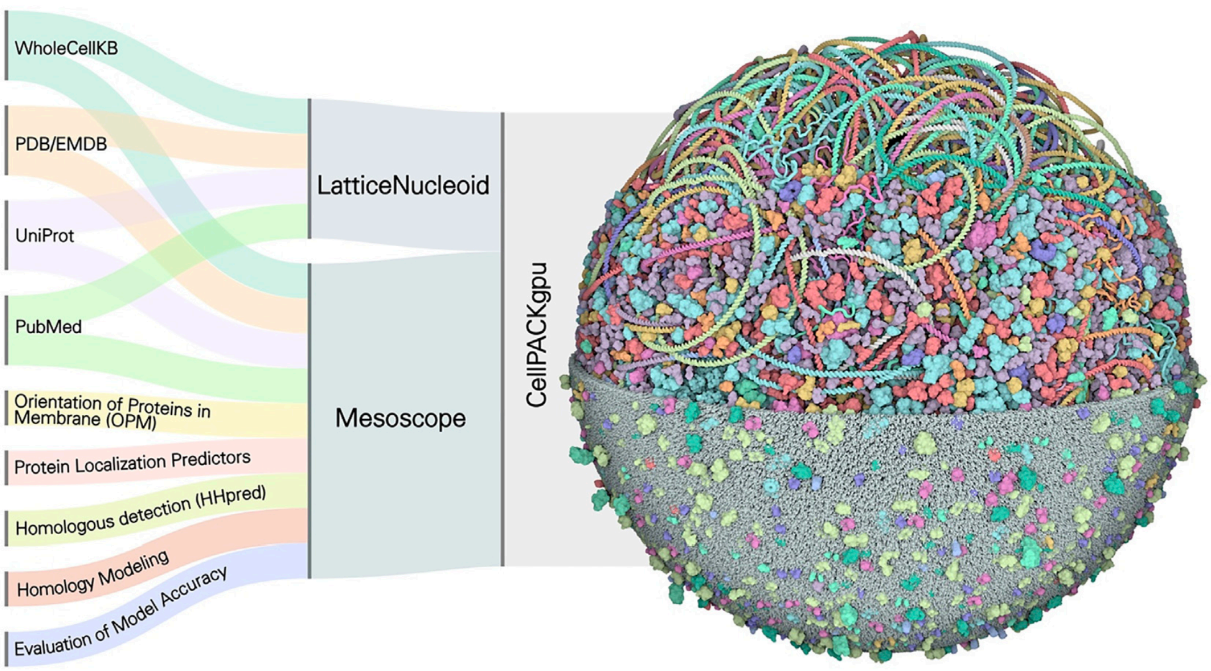

Figure 1: "Data integration to generate computational models of entire M. genitalium cells." (2) Data from a variety of sources, spanning molecular structure to the organization of nuclear DNA, are integrated into Mesoscope (3) and Lattice Nucleoid (4) and rendered with CellPACK (3).

Part 2: Technology and methods

Types of data and levels of detail

Although many types of data, spanning atoms to human populations, often includes behavioral information, behaviors are inherently temporal elements and are outside the scope of this writing, which will predominantly focus on methods of seamlessly integrating spatial scales. Yet eventually, simulations of the arrangements of matter across scales will require the proper inclusion of component behaviors at each scale, because motion is an inherent property of our universe. Yet for now, this work aims at uncovering technologies and methods for integrating ‘static’ arrangements of matter, be it subatomic particles, or the atoms they create, or the molecules atoms create, or the cells molecules create, or the tissues cells create, or the organs tissues create, or the organisms organs create, or the ecosystems and societies organisms create, or the planets, solar systems, galaxies and universes inhabited and explored by these organisms.

Current examples of where this information is distributed and how it is aggregated include, but are definitely not limited to: A) Angstrom and nanoscale (0.1-100 nanometers) databases: 1. Quantum Expresso (software for determining collective electron structure and arrangement) (5), 2. AtomWork Inorganic Material Database (over 80,000 crystal structures of the atomic arrangement of different materials) (6), 3. PubChem (millions of structures of the atomic arrangement of various chemical compounds) (7), 4. RCSB Protein Databank (nearly 200,000 experimentally validated atomic arrangements of proteins and other molecules, and over 1 million computationally-derived molecular structures) (8), and so on. B) If we expand our spatial magnitude into the mesoscale, as defined by Dr. David Goodsell to span nanometers to micrometers (9), capturing the size of individual atoms (~0.3 nanometers) composing individual molecules (~5-15 nanometers) composing individual organelles (~1 micrometer or 1,000 nanometers) within individual cells (~10 micrometers or 10,000 nanometers), additional databases include: 1. The organelle proteome (molecular-resolution map of protein arrangement in cellular organelles, and part of the larger Human Protein Atlas Project) (10), 2. The Single Cell Portal (database including thousands of studies mapping the spatial arrangement of gene expression in individual cells) (11), and 3. The Human Cell Atlas (growing database of the spatial arrangement of human cells across all tissue types) (12).

Many fantastic resources across these tiny spatial scales alone (0.1 nanometers to micrometers) have been omitted here for space, in addition to a great number of additional databases for scales larger or even smaller, spanning the 'bulk' arrangement of trillions upon trillions of molecules into fluctuating atmospheric data, or the arrangement of planets and moons into solar systems, or the arrangement of solar systems into galaxies, and so on. We are only in our earliest stages of putting these pieces together into coherent experiences, and although there is still significant work in the road ahead, rapid technological acceleration is now making the externalization of seamless spatial exploration an increasingly probable reality.

Devices and user experience: views and code

Different technologies must be properly arranged into systems in order for us to seamlessly explore space outside of the mind. These technologies and methods may be both scientific and artistic. In starting with the types of technology we might use to freely explore spatial magnitudes of objects in our everyday experience, the phone is a likely candidate, although augmented reality glasses may also find applicability here. Towards making this a reality, it is helpful to map out a hypothetical user experience and then map individual elements of this experience into discrete views and code components. What might this experience entail? A simple example might be that the user taps an object within the frame of the iPhone camera during live capture as seen in Figure 2 (referencing a smooth zooming simulation from the WEHI institute, (13)), begins to zoom in to this object until the camera reaches maximum zoom (upon zooming in on a selected object, media begins to load), and at this point the camera *switches from reality to simulation* and uses style generation machine-learning to blend the zoomed-in camera object into microscopy or other data, at which point the user continues to zoom in until the simulation of a spatial scale of the next smallest order of magnitude is loaded, and so on. Therefore, examples of the discrete types of code required for such an application include: A) machine-learning based object recognition during real-time camera use, B) real-time connectivity to databases of multi-scale simulations of the arrangements of matter and C) style-transition machine learning.

For A) in brief, custom machine learning models that recognize specific images while using the iPhone camera, such this “Breakfastfinder” app (14), can be trained with the Turi-Create framework (15) and converted into a .mlmodel file that can be directly imported into applications in progress within the Xcode integrated developer environment. For B), significant work is still required for seamless connectivity to different databases of simulations across systems and scales, however, a simpler example of compiling relevant information is to collect and databank ‘smooth-zooming’ simulations, as is attempted in Table 1. These simulations will also soon be compiled and shared on an extension of my personal website. For C), style-generative adversarial networks hold potential and are currently under exploration for generating ‘landscapes’ of molecules, cells and so on, and eventually, helping to convert 2D landscapes into 3D topologies (16).

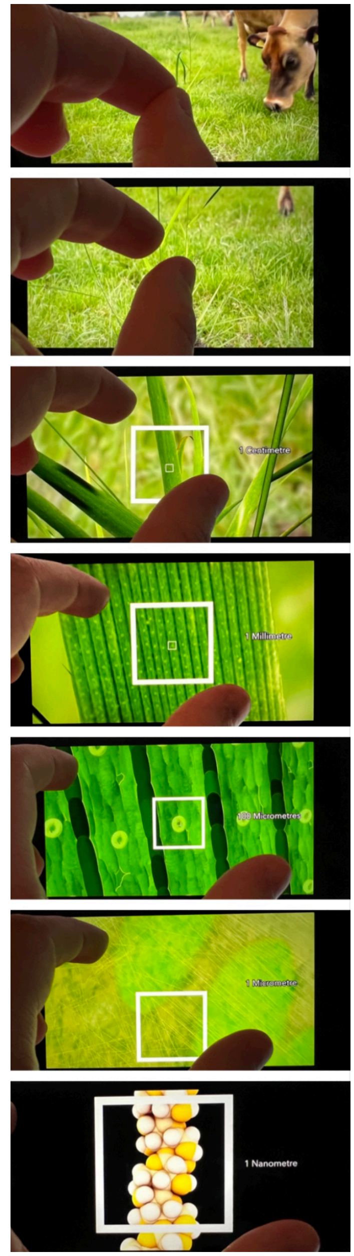

Figure 2: Hypothetical scale exploration user experience.

In addition to compiling code examples such as these, images, 3D models or other data pertaining to the arrangement of matter across spatial scales must also be stitched together. Below is perhaps the simplest possible method of doing this, resulting in a smooth but *discrete* (and thus not truly smooth), experience of zooming into different images pertaining to different spatial scales of human skin. In the short term, this spatial exploration of human skin experience will be improved by image and video editing techniques, but in the long term, perhaps the most desirable outcome is a massive, interactive 3D model.

Systems Explored	Link
Scale-comprehensive:	
From atoms to the universe, “IBM Powers of Ten”	https://www.youtube.com/watch?v=0fKBhvDjuy0
From atoms to the universe, "Cosmic Eye — Universe Size Comparison”	https://www.youtube.com/watch?v=8Are9dDbW24
From atoms to the universe, "Powers of Ten - Ultimate Zoom.” Disclaimer: sometimes discontinuous but still well done.	https://www.youtube.com/watch?v=bhofN1xX6u0
Atoms to our galaxy, “Epic zoom - atom to galaxy”	https://www.youtube.com/watch?v=RB3nzNNRxow
From a human to individual atoms, “Voyage into the world of atoms”	https://www.youtube.com/watch?v=7WhRJV_bAiE
Organic systems:	
Meters to nanometers within a plant cell, “Cellulose synthesis by plant cells. Powers of ten zoom.”	https://www.youtube.com/watch?v=Edy9EgqcAxg
Cellular (micrometer) composition of a leaf, Travel Deep Inside a Leaf	https://www.youtube.com/watch?v=Bf-RFPaZeAM
Molecular (nanometer) and cellular (micrometer) composition of wood, “Zoom into the Cellulose of Wood”	https://www.youtube.com/watch?v=_3FD9G0uFaM
Carbon atoms (angstroms) to cells within the human body (micrometers), “Exploring the Nano World”	https://www.youtube.com/watch?v=wIXAzDANmKw
Smooth-zoom from tissues (millimeters) to cells (micrometers) to molecules (nanometers), “Inner Life of a Cell | Protein Packing Animation”	https://www.youtube.com/watch?v=uHeTQLNFTgU
Smooth-zoom from a cell (micrometers), to an organelle (mitochondria), to molecules within it, “Glycolysis”	https://www.youtube.com/watch?v=xYR7Hx0CvTY&t=92s

Systems Explored	Link
Inorganic Systems:	
Atomic arrangement of steel, "Exploring the atomic composition of steel"	https://www.youtube.com/watch?v=dNvdrpEmS48
Fine structure of a microchip, "Zoom Into a Microchip"	https://www.youtube.com/watch?v=Fxv3JoS1uY8
Space:	
"To scale; the solar system." NOT a simulation or smooth-zoom, but a fascinating and well-done real-world recreation of the spatial scale/distance between the planets of our solar system.	https://youtu.be/zR3Igc3Rhfg
"Zoom into the Cartwheel Galaxy"	https://www.youtube.com/watch?v=bfAjQX-eapc
"Zoom into Pillars of Creation"	https://www.youtube.com/watch?v=lj3t_gjuXWk
"Zooming in on the Andromeda Galaxy"	https://www.youtube.com/watch?v=TijClV4uHIk
"Zoom into Carina Nebula Captured by James Webb telescope."	https://www.youtube.com/watch?v=QHa2jnei_MM
Fun bonus:	
"The Simpsons Intro: Powers Of Ten"	https://www.youtube.com/watch?v=FEuEx1jnt0M

Table 1: Compilation of multi-scale media and simulations

Simple and intuitive digital art methods for stitching together different spatial scales: skin

It is now possible for anyone with technology such as an iPad to easily create a simulation pertaining to the experience of navigating through different spatial magnitudes. This can be achieved by repurposing increasingly popular methods from the digital art space for creating 'infinite art' loops. The simple workflow used below is available for free on YouTube:

How To Make Infinite Zoom Art Tutorial on iPad, https://www.youtube.com/watch?v=S1kQLmw2eQg. By cutting windows of approximately appropriate size into each image in the Procreate and sequentially transferring these images into the Endless Paper app as seen in Figure 3, a massive image containing photos of my thumb (millimeters), microscopy images of multiple skin cells (hundreds of micrometers) (17) and individual skin cells (tens of micrometers) (18), a simulation of the atomic structure of DNA wrapped around histone proteins within the nucleus (nanometers) (19), and a simulated representation of a single oxygen atom (angstroms) (20).

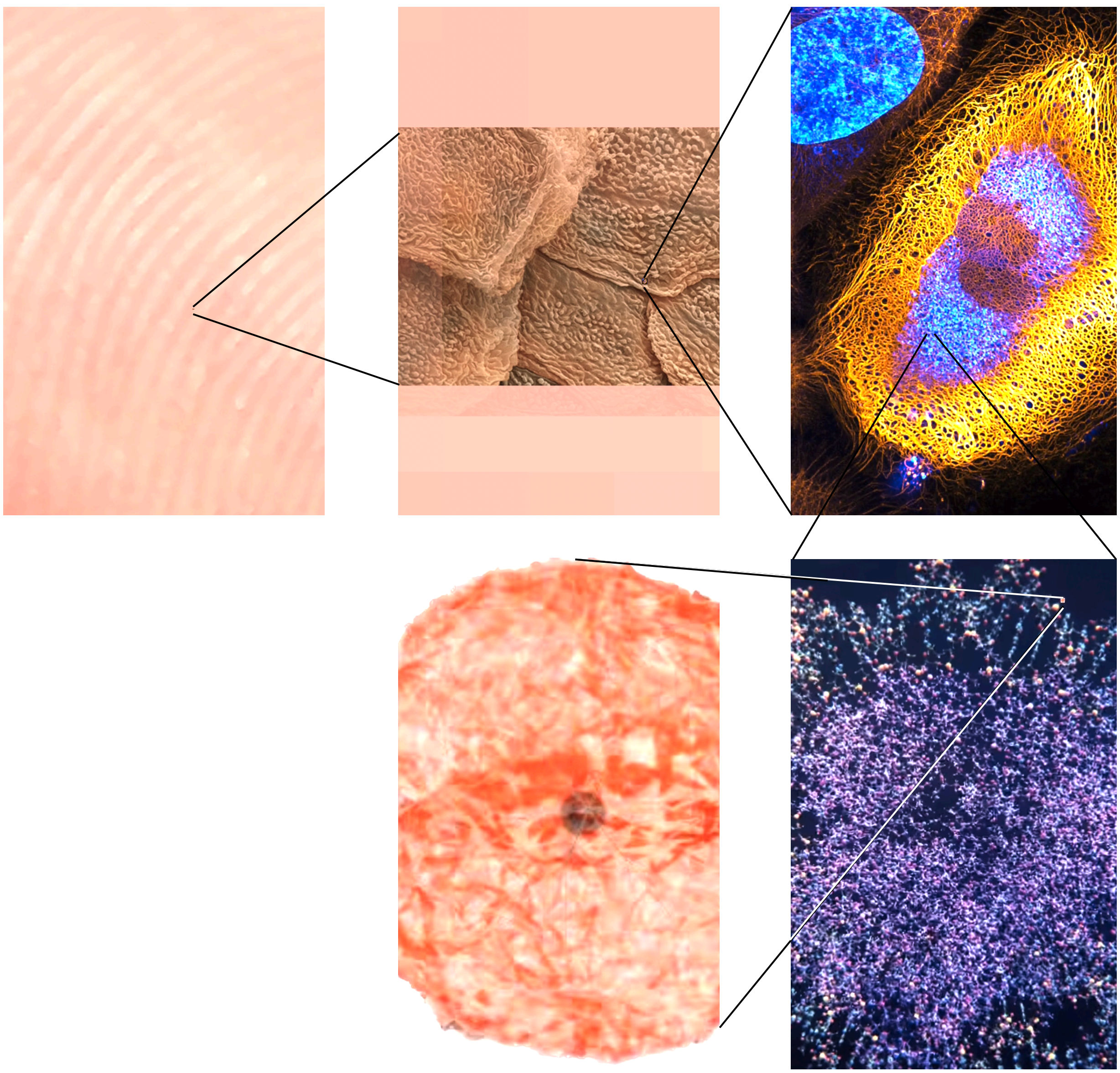

Figure 3: Using digital art tools to stitch together multiple images representing arrangements of matter at different scales within a view of human skin.

Future Directions

The technological externalization of the mind's capability of seamlessly moving through space will, to the hope of the author, be transformative to how we come to understand and explore natural phenomena. Imagine a grade-school child using a device to zoom in to see hypothetical simulations of the arrangement of molecules in a cell within a flower in from of them, and then in the same continuous experience, zooming back out to reaffirm their position in the current state of the solar system and galaxy. Currently, different spatial scales tend to be compartmentalized in textbooks, which makes it unnecessarily difficult for readers to see how one scale fits within another. Yet the rapid acceleration and merger of both scientific and creative tools shows promise towards the possibility of letting individuals freely navigate across spatial magnitudes, and enriches the capacity to experience one's immediate environment when one can push an exploration of space to infinity in nearly any direction. Indeed, extending the mind's instrument of spatial exploration into external technologies is not even limited to our immediate environment, for machine learning is easily capable of recognizing not only physical objects in one's surroundings, but images as well, meaning that anything which falls upon our vision has the potential to quickly remind us, lest we have forgotten, that it is an object of great wonder and mystery!

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