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Tabula Rasa: Mechanism, Intelligence, and the Blank Slate in Computing and Urbanism

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Cover Page Footnote
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ABSTRACT

This project critically examines the “tabula rasa” in computer science and urbanism, questioning the emptiness it describes in landscape through an exploration of its origins in terms of intelligence. Experimentation with tabula rasa in machine learning, where the term describes the originally empty knowledge base of a thinking machine, demonstrates the fallacy of a truly independent artificial intelligence and provides a critical lens through which to interpret the tabula rasa in urbanism. Revisited from this perspective, the case study of Hiroshima, Japan—an iconic example of the urban “blank slate” brought about through total demolition—can be read as a layered complex of historical and cultural components that, like a neural network, resist the separation of information and mechanism. The tabula rasa forms a theoretical conduit across computing and urbanism, enabling a novel transposition of the machine learning framework to cultural landscape analysis.

INTRODUCTION

Tabula rasa is a Latin term meaning “blank slate.” It means empty, razed, scorched, evacuated—but it also connotes wild, unbiased, and innocent. It means new birthplace and open opportunity, a dramatized idea of a fresh start. It appears in various creative and scientific disciplines, each of which ascribe to it a new form and materiality but all of which allude to the fond mythology of a completely new and innocent origin point.

This paper will investigate the tabula rasa across the fields of computing and urbanism, using the mechanistic revelations of machine learning experiments to drive observations of the tabula rasa in an urban landscape. It takes a field characterized by programmatic abstraction and immateriality and holds its approaches up to the light of an immediate, immersive, full-scale, and emotionally triggering landscape. It intends to illuminate not only the captivating instability of the tabula rasa in each context, but also the powerful potential of computational thinking as a framework for parsing the nuances of complex urban systems.

In computing, the tabula rasa describes the empty structure of an artificial intelligence capable of learning without any innate knowledge. It implies the miraculous production of understanding from a blank and formless mechanism. To demonstrate the artifice of this notion, I discuss a set of experiments that use an unsupervised machine learning model—an autoencoder—to interrogate an aspect of inbuilt bias or “knowledge” embedded in the neural network, demonstrating the insubstantiality of the computational tabula rasa by exposing the fundamental dependence of machine learning on innately ingrained information.

I translate insights from this experiment to the field of urbanism, where they inform an analysis of the tabula rasa produced by the atomic bomb in Hiroshima, Japan. Architecturally, the tabula rasa is conceptualized as the empty site: it describes unbuilt environments, or wilderness, but also sites that were once built and somehow razed by human violence or natural disaster. I pursue the traces of the erased in the reconstructed, demonstrating through the case study of Hiroshima’s Peace Memorial Boulevard that urban systems physically obliterated still exert an enduring influence through the culture of memory and the imperative of resilience.

My analysis of the tabula rasa in landscape is shaped by the intellectual framework of computational intelligence. I address the urban site with attention to the layered transformations of the neural network and interpret changes in the built environment as echoes of the mechanistic opacity and iterative clarity of a machine learning process. I metaphorically apply the procedures and mechanisms of machine learning to this analysis of the urbanist tabula rasa with the intention of introducing a new application of computational methods to the practice of urban studies, exploring a notion of the landscape as an intelligent machine. Through this novel critique of the tabula rasa, I reveal the utility of computational thinking for urban observation and explore the potential of a mechanistic approach to historical analysis.

ORIGINS: HISTORY AND THEORY

The tabula rasa denotes emptiness charged with potential. It is a latent intelligence, a promising void, a machine awaiting its ghost. It has made a long journey through various disciplines and movements in Western thought: the concept originated in philosophy, then wove through various notions of human nature to psychology, where its impact on theories of knowledge and learning brought it ultimately to computer science by way of artificial intelligence (AI).

I trace the origins of the tabula rasa across various disciplines and movements, from its origin in philosophy to its application in artificial intelligence. I argue that the tabula rasa is a powerful concept for understanding the relationship between humans and machines, and for exploring the potential of computational thinking in the field of urban studies.
Aristotle’s 350 BC treatise *De Anima*, where he philosophizes that “the mind is in a sense potentially whatever is thinkable, though actually it is nothing until it has thought,” (Book I) and compares this immaterial intelligence to the characters anticipated by a “writing-tablet” upon which nothing is written yet. This statement establishes the enduring cognitive metaphor of a promising empty vessel, awaiting the imminent but foreign intelligence that will inhabit it.

The tabula rasa later appears in the seminal “Essay Concerning Human Understanding” written by British political philosopher John Locke (1632-1704) in 1689 (Duschinsky 512). Locke’s adaptation of the metaphor, which renders Aristotle’s “writing-tablet” as a “white paper” (initiating the evolution of the tabula rasa according to changes in the technology of intellectualism), equates the empty page to the human mind at birth (Locke and Woolhouse 20). He envisions the infant consciousness as a formless intelligence, originally devoid of innate knowledge—or, therefore, any natural evil—that receives information and learns to process it purely by the inscription of sensory input (Pinker 5).

The Lockian tabula rasa informs the work of English cryptanalyst and mathematician Alan Turing (1912-1954), who is widely considered the father of theoretical computer science. Turing’s postwar writings on artificial intelligence are the founding manuscripts of the modern field, and it is through his work that the tabula rasa enters the computational vocabulary. In a 1950 issue of *Mind*, he wrote:

> Instead of trying to produce a programme to simulate the adult mind, why not rather try to produce one which simulates the child’s? If this were then subjected to an appropriate course of education one would obtain the adult brain. Presumably the child brain is something like a notebook as one buys it from the stationer’s. Rather little mechanism, and lots of blank sheets. (Turing 19)

Turing carries forward the idea of the uneducated brain as a blank substrate and again updates the “white paper” to a “notebook” freshly purchased. Important in Turing’s notion of the tabula rasa is his distinction of mechanism from information: the empty and innocent consciousness he describes possesses no innate knowledge written across its pages, but it does require some minor mechanism to bind them together. Then, is the “tabula rasa” here the empty page or the notebook itself? An investigation of that question—of technically locating the computational tabula rasa—must pursue the distinction between information and mechanism.

**EXPERIMENT**

To empirically evaluate the computational tabula rasa, I conducted an experiment on my own machine learning model. I built a simple autoencoder to perform the task of reducing and reconstructing images of a handwritten zero and a handwritten one. I built the model properly and trained it successfully so that it was capable of reconstructing each type of image correctly. Then, I interrupted this learning by modifying an aspect of the original model I would classify as “innate knowledge” and demonstrating the effects of these modifications on the network’s ability to learn. The impairments brought on by my interventions demonstrate that even unsupervised learning relies on a certain quantity of inbuilt information.

The substrate of this process is the artificial neural network (neural net), a computing system vaguely inspired by the biological neural networks that make up the human brain. A neural net is composed...
of artificial neurons that build up signals and “fire” when they reach a certain value threshold, similar to how their biological predecessors behave (Fig. 2). These neurons are connected to one another in multiple layers that apply different transformations to the data they take as input: as learning proceeds, the various “weights” that temper the outputs of each layer are modified until a functional composition is achieved.

The neural network described here is an autoencoder that conducts unsupervised learning. Its goal is to learn an encoding (an efficient data representation) for a given data distribution by filtering out all but the most defining features that differentiate data points from one another. This architecture is composed of an encoder, which compresses the input data to a dense and efficient encoding by a process of dimensionality reduction, and a decoder, which maps that encoding to a reconstruction of the original input. This reconstruction is typically a rough approximation of the original it references because the encoding process forces the network to focus exclusively on the most definitive aspects of the data it represents.

In this case, the encoder receives images 28 by 28 pixels wide, which the model reads as matrices of 784 numbers such that each image is a data point in 784 dimensions. The encoding is only two dimensions. Such stringent dimensionality reduction forces the autoencoder to capture exclusively the differentiating features of the data, and it also allows the learned encodings to be plotted on a Cartesian plane, which offers a compact visualization of the latent space in which the encoding operates. Figure 3 illustrates this process of dimensionality reduction and reconstruction in terms of the autoencoder architecture.

To investigate the computational tabula rasa through this autoencoder, I performed a set of experiments that expose the relationship between innate knowledge and functionality in machine learning. The experiments focus on the activation function: a mathematical entity that determines the firing threshold for artificial neurons.

In the brain, a neuron fires only when a sufficient electrical impulse builds up to provoke an action potential, which suddenly releases a charge down the neuron’s axon with enough intensity to transmit a signal to the surrounding cells. The activation function imitates this behavior, acting as a mathematical threshold that defines the range of input values forceful enough to elicit a “firing” output from an artificial neuron (Fig. 4).

My experiments demonstrate the importance of activation functions to the quality of the system’s training, evidenced in Figure 5. In a sequence of experiments starting with the original network (Trial 0) followed by two modifications to the activation function (Trials 1 and 2) and an iteration of the network trained with no activation function at all (Trial 3), the network’s functionality falters and disintegrates. As the clustering of data points in the autoencoder’s latent space (plots at left) loses clarity, the reconstructed images it outputs (right) become noisy, unfocused, and poorly differentiated.
These results indicate that avoiding such failure outputs requires not only the inclusion of an activation function, but the selection of the right one.

The activation function is assigned at the initialization of the network before any training data passes through it. In this way, it intervenes in the original Aristotelian “writing-tablet”: a blank surface where nothing is written yet and no learning has taken place. However, if the network’s functionality responds to the manipulation of the activation function within that dormant substrate, it must account for some form of “knowledge” innately ingrained in this computational tabula rasa. Thus, as Turing implied, it can be said of the artificial neural network what cognitive psychologist Steven Pinker observes of the human brain: “Something in the mind must be innate, if it is only the mechanisms that do the learning” (34).

Pinker offers an alternative to Turing’s notion of a mind with “little mechanism and lots of blank sheets,” identifying learning processes as innate elements of intelligence that cannot be differentiated from knowledge itself. He implies that blankness imbued with mechanism is not truly blank, inviting the proposition supported by my experiments that the very anticipation of knowledge—a fundamental aspect of the tabula rasa since Aristotle—relies on some innate structure. Nowhere is this indelible linkage between information and mechanism clearer than in artificial intelligence: machine learning is achieved by constructing the agents that perform the component calculations in such a way that they produce the desired learning framework. Accordingly, knowledge achieved by these systems is not an effect of simulated genius but instead a product they were trained to manufacture based on clear metrics of success and failure. In this way, a given model’s desired output and the details of its construction are innately and inextricably linked.

**TRANSLATION**

My landscape analysis draws on the history of the urbanist tabula rasa as well as a long lineage of architects likening cities to intelligent organisms or mechanical automata, of which my metaphorical use of machine learning is both. The computational tabula rasa primarily refers to an originary state of emptiness, encapsulated in a blank slate yet unwritten upon, a child’s brain yet uneducated, or a neural network before its training. However, another version of the concept exists. According to Duschinsky, the original Latin tabula rasa referred to a writing tablet after the inscriptions in its wax surface had been removed. He claims that “a more precise translation would be ‘a slate that has been blanked’, the effect of the erasure of text,” indicating that the more accurate usage is not Locke’s “white paper” but nineteenth century German philosopher Friedrich Nietzsche’s “to make room for something new” (46). It is toward this aspect of the tabula rasa, which emphasizes erasure rather than emergence, that I direct my architectural exploration.

The methodological precedent for this interdisciplinary approach lies with the various architectural thinkers who have envisioned the city as an organism or machine—related metaphors that tend to bleed together. Two of the most famous architects to draw this comparison, Frank Lloyd Wright (1867-1959) and Le Corbusier (1887-1965), offer demonstrative examples. Wright combined the idea of the city as a biological system with specific attention to the mechanical nature of its organs and processes in his seminal essay “The Art and Craft of the Machine,” describing the city of Chicago as a mechanized life force:

> There you may see how in the image of material man, at once his glory and his menace, is this thing we call a city… This wondrous tissue is knit and knit again and interknit with a nervous system, marvelously effective and complete, with delicate filaments for hearing and knowing the pulse of its own organism, acting intelligently upon the ligaments and tendons of motive impulse, and in it all is flowing the impelling electric fluid of man’s own life. (369)

Le Corbusier, whose work tended to “casually and without explanation treat the city alternately as organism and artifact,” famously summarized this metaphor in his image of an urban system as a “concrete biology” (Choay and Bratton 242). These descriptions of cities as both mechanical and biotic connect the theory of urban analysis to the parallel synthetic biology of the neural networks that carry out machine learning: through the metaphor of the intelligent mechanism, the city can be read as a sibling to the machine learning model, an alternative substrate for the biomimicry of artificial intelligence.
ARCHITECTURE

At 8:15 AM on August 6th, 1945, Hiroshima was illuminated by a noiseless flash from above (Hersey). Following that momentary flare, the city would make history as the first witness to the horrors of atomic warfare, suffering some of the most complete physical destruction ever inflicted on an urban landscape. Its reconstruction process after this devastating event represents not only an instance of total erasure and recovery, but also an opportunistic effort to revise the ethos of the urban environment. Hiroshima emerged from the blank slate of its post-atomic landscape with the objective of shedding the evidence of a long military past to become an International Peace Memorial City, as decreed by the Japanese government in 1949 (“Hiroshima for Global Peace” Plan Joint Project Executive Committee 8). The connotation of tabula rasa as “razed earth” makes Hiroshima the iconic example of the twentieth-century empty site, given the unprecedented completeness of its physical obliteration.

Hiroshima recalls not only the destruction but also the aspirational history of tabula rasa planning. Its reconstruction strategy involved a fundamental rebranding effort to draw the culture of an International Peace Memorial City out of what was once a military-industrial stronghold (Hersey). This total overhaul of Hiroshima’s international brand required a nationally legislated reconstruction plan, which brought about the overt representation of the city’s new identity through law. The programmatic aspect of this development strategy opens an entry point for its interpretation in terms of artificial intelligence.

Hiroshima’s reconstruction began under the crushing and humiliating weight of American occupation and with the imperative to memorialize the tragedies of the war while developing an ethos for moving forward. Architect Rem Koolhaas’ Project Japan (2011) details the psychological trauma associated with Japan’s rapid retreat from imperial projects to reconstructive ones: “The same architects and planners who had, in the ‘30s, projected vast new settlements on wide open spaces abroad were now confronted with their own cities transformed into radioactive rubble. From utopia to apocalypse in less than half a generation…” (12).

To support this effort in the city most deeply associated with the nation’s wounds, the National Diet enacted the Hiroshima Peace Memorial City Construction Law in 1949. Its first article asserts that “Hiroshima is to be a Peace Memorial City symbolizing the human ideal of the sincere pursuit of genuine and lasting peace” (“Hiroshima for Global Peace” 12). The law goes on to detail specific strategies for constructing public peace memorial facilities on the same timeline as the basic infrastructure necessary to revive and inhabit Hiroshima, designating land for “Memorial Places” with the same urgency applied to roads and sewage systems. The commemorative structures still stand today as the primary landmarks of the city, which literally rebuilt itself around them as its defining features. The Peace Memorial Boulevard is one of these commemorative urban elements: a 100-meter-wide transect of linear parkland and several lanes of traffic cutting a horizontal swath through the city. This wide arterial corridor, flanked with rectangular stands of shade trees and memorial sculptures, gives the city its equator. It is a longitudinal landmark for Hiroshima, imbuing everyday navigation with awareness of the city’s tragic history and optimistic aspirations for the future.

One might expect that this version of monumentality through empty space arose from an instinct to preserve the flat, open plane of the atomic tabula rasa. But in this case, the wide swath of unbuilt space was already in progress before the bomb dropped. The 100-meter-wide gap in Hiroshima’s otherwise dense urban fabric actually began as a wartime technology: the space it created between the two halves of the city was planned as a firebreak, intended to protect each side from bomb-seeded fires on the other by imposing a gap in combustible material wide enough that flames could not reach across (Takezaki). This project was urgent and ongoing: at

The Peace Boulevard creates an idyllic frontage for Hiroshima’s Peace Memorial City messaging, but the reality that it predates the atomic tabula rasa, and that it was originally a defense apparatus rather than a peacemaking one, invites a closer look at its embodiment of that message. The Peace Boulevard’s urban form was initialized as a war apparatus and still under construction for that purpose when its entire context was destroyed by the atomic bomb. Then, when the city was reconstructed, the same form reemerged and retained its importance but took on a new meaning as a representation of peace. This process of reduction and reconstruction recalls the machine learning architecture that revealed the computational tabula rasa (Fig. 6).
In the autoencoder described earlier in this paper, the encoder reduces the dimensionality of the input data until it reaches a compact representation called the encoding, and the decoder gradually expands this encoding into an approximate reconstruction of the original input. Essentially, the decoder receives a very basic and condensed version of an idea and tries to imagine the full-scale original from which it was derived. The lower the dimensionality of the encoding—the less information it conveys—the less definite the decoder’s reconstruction of it will be.

The forced translation of the Peace Memorial Boulevard from a defense apparatus to a nonviolent monument evokes the imprecise reconstructions of a decoder working from a very small encoding. In my autoencoder, the input images were reduced from 784 dimensions to two, which resulted in reconstructions that only roughly captured the content of the originals. Envisioning the post-atomic wasteland as an encoding, in which almost every detail of the original city had been erased and only the barest suggestion of its former structure remained, invites a translation of the autoencoder framework to the process of post-war urban reconstruction.

Under this metaphorical concept transfer, the Peace Memorial Boulevard’s present articulation can be read as a reconstruction of its original concept based on the extremely reductive encoding of its post-atomic state. The reconstructed Boulevard is an alternative approximation of its military predecessor, distorted through the transformative gauntlet of the war. This reformation is effective: the Boulevard continues to perform its most basic role as a firebreak despite the layers of new messaging applied to its public appearance, and though the manicured promenade of the present day creates a very different atmosphere from the panicked civilian demolition project of wartime, the actual form that carries out this function remains the same. The drastic dimensionality reduction of the atomic bomb erased the details of aesthetic and political messaging, but the Peace Memorial Boulevard remains an accurate reconstruction of its wartime predecessor in that the most basic elements of its physical expression remain in place.

A reading of the Peace Memorial Boulevard as a skewed mathematical reconstruction of its former self illuminates the inertia of the city through the mechanism of the autoencoder. It reframes Hiroshima’s self-reinvention as more of a pivot, in which the same urban patterns were repurposed to represent new messaging without undergoing any fundamental structural changes. Just as the MNIST images lost certain details when they were compressed and reconstructed by the autoencoder, the firebreak’s wartime purpose was glossed over when it became the Peace Memorial Boulevard, but its original structure remained intact. This phenomenon can be traced to Turing’s original conflation of information and mechanism, where the computational information of data is translated to an architectural information of form: even when the form of the city was erased, its mechanism remained, and went on to reproduce the same forms as before.

CONCLUSION

This paper has explained the richness of the intelligent machine as an analytical framework, using a philosophical-experimental interrogation of the computational tabula rasa to inform an exploration of the urban blank slate.

Through machine learning experiments, I pursued the distinction between information and mechanism, looking for a way to isolate the computational tabula rasa as an instance of total blankness in my model. I found that even the simplest unsupervised learning architecture could not function correctly in the absence of the innate information represented by the correct activation function. In other words, its mechanism could not be separated from the information it was designed to output.

The shared concept of the tabula rasa provided a conduit for interdisciplinary conversation between computing and urbanism, allowing the transfer of the machine learning framework to my analysis of the Peace Memorial Boulevard in Hiroshima, Japan. In this instance of urban erasure and reconstruction, I transposed the insights from my autoencoder to read the landscape in a new way, comparing the different meanings of the 100 meter-wide transect before and after the war to original and reconstructed figures of image translation. Like my computational experiments, this encounter with the tabula rasa reveals the durability of structure and the mutability of detail.

In an essay about the entropic potential of overgrown sites of urban neglect, artist Flower Marie Lunn muses, “The spatial experience of a city is composed of multiple grids and cordoned areas, each with its abstracted boundaries. Striated space extraordinaire, a city is layers upon layers of structures and meaning—epistemological bureaucracies in concrete, if you will,” evoking the interlaced layers of a neural net as well as the methodical choreography of their interactions. My urban analysis takes a similar view of the city and pushes this concept even further, explicitly drawing on the idea of a programmed computational system that produces and manipulates information according to logical procedures.

However, the information, or “knowledge” that I ascribe to the city diverges from the mathematical data analysis of machine learning. I conceptualize it more as a collective or distributed version of the “tacit knowledge” originally formulated by Hungarian-British polymath and philosopher Michael Polanyi (1891-1976), rendered as architectural form. This type of information is acquired through practice and cannot be articulated clearly, having more in common with mental muscle memory or instinct than with explicit knowledge. I approach the city as a network of the woven quality Lunn describes, that produces a set of spatially-expressed habits akin to Polanyi’s tacit knowledge. This urban paradigm is both derivative of the neural network and an intelligent machine all its own.

The conclusion to this investigation requires the introduction of a final concept, which is the Computational Theory of Mind. It was this idea that originally defined cognition as a form of information processing, mobilizing insights from artificial intelligence research in the 1990s to expunge the tabula rasa from the field of psychology by connecting the fundamental molecular and electrical mechanisms of cognition to the intelligence they produce. It hypothesizes that rational thought can emerge from the combination of many instances of low-level logic synergistically networked to create the complex patterns that give rise to cognition (Pinker 32).

Pinker, referencing the Computational Theory of Mind, observes...
that “the sister field of artificial intelligence is confirming that ordinary matter can perform feats that were supposedly performable by mental stuff alone” (33). This work falls into that sister field, demonstrating, through interrogations of information and mechanism in computing and urbanism, that the framework of learning is not limited to intelligence of any kind but can be applied to any system of networked logical components, visible or invisible. The city is one of these, but many more exist.

REFERENCES


Claire Gorman’s desire to test her education against theoretical questions landed her in Valdivia, Chile and Hiroshima, Japan for her research. Gorman’s research explores the notion of the “tabula rasa” or blank slate in both computer science and urbanism. The concept of a tabula rasa in computer science refers to a “thinking machine that’s able to learn, starting from nothing,” and in urbanism the tabula rasa refers to “represents an empty [physical] site.” Gorman visited Hiroshima, Japan, where an atomic bomb infamously razed the landscape into an urban tabula rasa in 1945. Gorman also visited Valdivia, Chile, which was “the site of the largest earthquake ever recorded” in 1960. The two sites gave Gorman a chance to explore “the concept of tabula rasa as a man-made erasure [in the case of Hiroshima] and as a natural erasure [in the case of Valdivia].” Gorman majored in Computing and the Arts, which combines computer science and architecture. Although the major offers no classes that combine both disciplines, students are able to find and explore “the theoretical crossover” of these disciplines on their own. The tabula rasa, a phrase that exists in both fields, gave Gorman an opportunity to do just that.

Although Gorman graduated in 2020, she was involved in many different extracurriculars during her time at Yale. Gorman was an involved leader in the First-year Outdoor Orientation Trips (FOOT) program and eventually spent a summer working for the Guadalupe Mountains National Park Service in Texas. Gorman was also the curriculum developer for Code Haven, “a student organization that visits New Haven public elementary schools weekly and teaches computer-programming principles.” Gorman also worked on a project in the Urban Ecology and Design Lab called the “ThermoGreen Wall,” where a vertical wetland was constructed on the walls of buildings to explore their cooling effect on water. Since graduating, Gorman has joined the MIT Senseable City Lab as a research specialist.

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