Lecture Notes in Morphogenesis
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Algomedia. The Image at the Time of Artificial Intelligence

Springer

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Chapter 7
Algorithmic Economies of Light. The SARS-Cov-2 Micrographs as Algo-Images

Ruggero Eugeni

Abstract This chapter investigates algorithmic imaging dispositives, or *algo-images*, by situating them within the broader context of a political economy of light and its historical transformations. Initially, the chapter explores a detailed case study focusing on micrographic imaging technologies, encompassing both optical and electronic microscopy, utilised to visualise the morphology, behaviour, and material composition of the SARS-CoV-2 virus. The analysis elucidates how micrographic dispositives integrate two distinct image-production paradigms: one reliant upon manipulating electromagnetic energy flows, and another centred around digital data processing. Subsequently, the chapter argues that these paradigms correspond to two successive regimes within the political economy of light: the modern one characterised by *techno-images*, and the contemporary one dominated by *algo-images*. The conclusion highlights both divergences and continuities between these regimes, emphasising their common epistemological and practical aim: facilitating the cognitive and operational appropriation of reality. Ultimately, this analysis contributes to a deeper understanding of how contemporary visual technologies shape our relationship with the world through acts of appropriation and expropriation of the visible, which are presently carried out through data capture and management—both visual and invisual.

Keyword Algorithmic images · Microscopy imaging · Political economy of images · Techno-images · SARS-CoV-2 imaging

7.1 Islands in the Stream

The black and white image shows two whitish, rounded and bare islets seen from above. A crown of rocks surrounds each. All around, a milky sea troubled by mysterious currents. It is January 24, 2020. Less than a month has passed since December

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31, 2019, when the Chinese government notified the World Health Organisation of the spread of a new virus, provisionally labelled 2019-nCoV. The virus remained faceless for twenty-four days until scientists from the Chinese Centre for Disease Control and Prevention released the first image: the two crowned islands [52].

The first visualisation of the virus is the prologue to a story as complex as it is exciting: that of the use of micrographic images in virology's battle against SARS-Cov-2 [11, 31]. Visualising it is not enough to defeat the virus: you need to understand its mechanisms of movement, how it attacks human cells, and its internal conformation. These are all tasks in which micrographic images prove to be irreplaceable tools: not only means of information and dissemination but also practical *operational* objects [36].

In the first part of this chapter, I will follow the main stages of this story. In the course of the narrative, it will emerge that the images we are talking about present a peculiar characteristic: they are both *technological* (i.e. produced by management of electromagnetic flows aimed at engendering stable traces) and *algorithmic* (i.e. created by the processing and visualisation of dynamic data sets and data cubes). In the second part of the chapter, I will try to show that the two logics, although often intertwined, are distinct and that to grasp this distinction fully, we need to adopt the point of view of a broadened political economy: more precisely, the break that separates technological images from algorithmic ones refers to a different articulation of the *political economy of light*, which, from being a resource used to produce images, becomes an instrument for data extraction. But are these two economic regimes radically different? Or does the interweaving in micrographic technologies indicate an underground continuity between them?

7.2 Micro-imaging Warfare

7.2.1 How the Virus Looks like

The Chinese researchers arrived first in the frantic race to take a picture of the new virus. However, almost by chance, the Peter Doherty Institute for Infection and Immunity in Melbourne had obtained the same images a few days earlier but had not released them due to the quality of the image, which was deemed insufficient. Both groups worked with a *Transmission Electron Microscope* (TEM). This device does not use light rays to produce images but electrons. The reason is simple: as Ernst Abbe had demonstrated as early as 1873, the diffraction of rays related to the wavelength of light limits the resolution of *optical* microscopes to 200 nm (a nanometre is the billionth part of a metre). The primary means of circumventing this "diffraction barrier" (not the only one, as we shall see) has been *electron* microscopy and the resulting photomicrographic productions [21, 37].

Although the oscilloscope (the instrument for measuring electric current that displays electron flows on a phosphor screen) had been invented as early as the

late nineteenth century, it was not until 1931 that a working group at the Technical University of Berlin experimented with the possibility of using such a device to make magnifications. Since the wavelength of electrons is much shorter than that of light, it is possible to break through the light diffraction barrier to reach a definition down to 0.2 nm. Subsequent developments, mainly due to the German company Siemens during the 1930s, perfected the *Transmission Electron Microscope* (TEM)—also thanks to the forced labour of prisoners in some concentration camps where Siemens built its production laboratories. In the TEM, a beam of electrons, once emitted from a source, is condensed through an electromagnetic field (a "lens," but the term is metaphorical) and then led to pass through the sample to be analysed. The resulting electronic print is "rarefied" by other electromagnetic fields and then projected onto a sensitive surface such as a phosphor screen.

At present, the screen has been replaced by a grid of sensors and electronic-digital transducers that transform the flow of electrons into a data set, which, after suitable refinement steps, can give rise to an image such as that of the two islets. In this respect, current research (also stimulated by the wave of analyses relating to SARS-CoV-2) is making enormous progress in applying machine or computer vision algorithms to the "raw" digital images produced by electron microscopes [47]. These algorithms perform several operations previously delegated to human agents [34]: they enhance image contrasts (*preprocessing*); identify the relevant areas and shapes by separating them from the "noise" of the context (*segmentation, feature extraction*); recognise the components thus isolated (*classification*: [7]), follow a particular shape within subsequently captured images to grasp its displacements and transformations (*tracking*); carry out automatic colouring (*staining*: [29]); artificially implement image resolution (*restoration/reconstruction*).

Scholars often link the origin of machine or computer vision to the introduction of the Perceptron, the first device capable of recognising visual shapes, in 1957 [13]. However, it began to be systematically applied to microscopy in the second half of the 1990s and underwent a sudden leap forward with the advent of machine learning algorithms, often labelled as Artificial Intelligence, in the second half of the 2010s [2]: scientists thus moved from algorithms facilitating hand-designed procedures and from "shallow learning" algorithms to "deep learning" ones [25, 26, 33, 39]. In this sense, the experience of the epidemic has been a decisive boosting factor, either through the use of algorithms inspired by human visual recognition, such as *convolutional networks* [3] or more recently through a new generation of algorithms inspired by linguistic understanding, such as *Large Language Models* [15].

In any case, TEM allows researchers to visualise the new virus (whose diameter measures between 80 and 120 nm) with sufficient definition. Thus, in less than a month, the virus was given a shape: on January 30, 2020, the US Center for Disease Control and Prevention (CDC) presented to the world Spiky Bob, an expressive CGI (Computer Graphic Imaging) image based on micrographic photographs taken with electron microscopes [20]. It is a proper mug shot, and as is often the case in crime fighting, the attribution of a well-defined face preceded the assignment of an exact name.

7.2.2 How the Virus Moves

In fact, it was only on February 11, 2020, that the virus received its official name: SARS-CoV-2. Two days later, on February 13, the Rocky Mountain Laboratories, part of the National Institute of Allergy and Infectious Diseases, or NIAID (an influential research centre headed by Dr Anthony Fauci, President Trump's pandemic crisis advisor), presented a series of entirely new images of the virus, much more realistic than the Chinese ones, with vivid colours and accurate lighting. The images were not only directed at scientists: they were disseminated by the NIAID on its Flickr account and, from there, widely relaunched by the media. It is evident that there was an intention to publicly promote the centre's image, metonymically aligning its visualisation capabilities with its ability to detect and combat the virus, thus justifying the substantial funding it receives.

The technological basis accounts for the vividness of these images: NIAID obtained its images using a different technology from TEM, the *Scanning Electron Microscope* (SEM). This device, too, is based on the use of electrons: it originated in the late 1930s as a refinement of TEM and has been marketed by DuPont since the 1950s under the name "Stereoscan." In this case, the *primary* beam of compressed electrons travels along the specimen line by line and is reflected by its surface; this process gives rise to a *secondary* flow carrying information about the surface topography. Originally, the "brush" of secondary electrons was amplified and visualised on a cathode ray tube with a phosphor screen. Today, this process involves converting the electrons into a grid of data, which is then processed by a series of algorithms. The result is less potent than TEM's (the maximum resolution is currently about 1 nm), but the images are more vivid, textural, and have a "tactile" feeling. They can also be digitally coloured: in an NIAID image, for instance, yellow ochre virions emerge from the body of a cell they have previously infected and colonised ([22], see also [4]).

The *second* direction of visual virus control thus shifts its focus from how the virus appears to how it acts. Other laboratories, however, considered images obtained employing SEM technology with some criticism (let us not forget the competition between research centres, given the funding that a good, adequately communicated discovery can secure). In particular, on March 5, 2020, a group of researchers from the Southern University of Science and Technology in Shenzhen presented the first virus images obtained through a *Cryogenic Electron Microscope* (Cryo-EM) [32].

Cryo-EM was introduced in the 1980s from the ascertainment that the electron beam from TEM sometimes damages the sample; hence, the idea of subjecting preparations to very rapid cooling to cryogenic temperatures (below about 180 °C). This idea earned its inventors Jacques Dubochet, Joachim Frank, and Richard Henderson the Nobel Prize in Chemistry in 2017. One of the advantages of this technique is that the virus is "frozen" in its context and possibly while it is acting; therefore, micrographs pass from a studio pose to "live" snapshots. Furthermore, since it is possible to freeze successive phases of the same action (e.g. the act of penetrating a cell membrane), it is also possible to recompose an animated sequence of that action

[24]. But there is more: the frozen sample can be "filmed" from different angles: scientists speak in this case of *Cryo-electron Tomography* (Cryo-ET); once fused, the resulting data can be visualised as a three-dimensional image, which researchers can rotate according to their needs [51], possibly with the aid of augmented or virtual reality viewers [43]. The algorithmic processing processes already observed for other electron microscopes are crucial in the case of the Cryo-ET, which "uses AI to automate the data analysis steps of particle picking, 3D map reconstruction, and local resolution determination" ([8]; see also [19, 42]). In other terms, even more than in the previous cases, Cryo-Em and even more Cryo-ET devices collect and process far more data within the data sets and data cubes than they display.

The results are remarkable. For instance, a group of researchers coordinated by Dr Gerhard Hummer of the Max Planck Institute for Biophysics in Frankfurt published a significant article in the October 2020 issue of the journal *Science* [48]: Cryo-ET led them to analyse "in situ" the movement of SARS-CoV-2's spikes (the S-proteins), and thus demonstrate the existence of three joints, which the researchers called "shoulder," "elbow" and "wrist": it is precisely the extreme agility of movement allowed by these appendages that makes SARS-CoV-2 so dangerous compared to other coronaviruses. The researchers showed all this in a sequence of images that reconstructed the virions' movements, just as Muybridge's photographs in the nineteenth century reconstructed the horse's gallop inside the zoopraxiscope.

7.2.3 How the Virus Acts

At this point, an unexpected development emerges. Optical microscopy, initially sidelined because of the diffraction barrier, makes a comeback. In fact, since the end of the nineteenth century and throughout the twentieth century, scientists have devised various techniques within light or optical microscopy to circumvent the diffraction barrier. A large family of methods is linked to the use of *fluorescent* reagents to mark the substances to be observed: the first microscope using this technique was developed by Oskar Heimstaedt in 1911; in 2014, Stefan Hell, a scientist of the Max Planck Institute, received Nobel Prize in Chemistry for his pioneering work in the field of ultra-high resolution fluorescence microscopy. In this case, the beam of electromagnetic components does not directly illuminate the specimen but activates these fluorescent reagents: the photons emitted by the sample are captured by the optical lens system, fixed on a surface and then transformed into an image. In other words, the process shifts from utilising reflected or refracted light to capturing *emitted* light.

Fluorescence allows optical microscopes to access forms of super-resolution microscopy [38]. Yet, it presents a problem: since it is activated in all focal planes of the specimen, it makes it impossible to distinguish its different levels. The solution is the Confocal Microscope, patented in 1955 by one of the future fathers of artificial intelligence, Marvin Minsky. In this case, two symmetrical and mutually aligned pinholes limit both the projection of the ray that excites the fluorescence (a reduced

area at a time is illuminated) and the scope of the objective that allows it to be seen (a reduced area at a time is framed); hence, the sample is moved regularly while the photons gradually emitted are captured, amplified and deposited on an electronic receptive surface that stores them until the image is completed. If the use of Cryo-ET recalled the origins of cinema, in this case the analogy with the television apparatus is obvious; indeed, one of the ancestors of this technique is the "electric telescope" patented by Paul Gottlieb Nipkow in 1884, on which the first model of television device is also based. In recent models, the light beams that trigger fluorescence are replaced by laser beams: this is the case with Confocal Laser Scanning Microscope (CLSM); some advanced models, such as Stimulated Emission Depletion (STED) *Microscope,* can achieve very high resolutions, up to 40 nm. In this case, too, photons resulting from the process are captured by digital sensors, translated into data sets and then processed by algorithms that sharply improve "the signal-to-noise ratio, spatial resolution, temporal resolution and multi-colour capacity of live-cell imaging" [41: 443].

The confocal microscopes and fluorescence devices in general have various limitations: for instance, the emission of photons by fluorescent substances is time-limited—scientists speak of a limited "photon budget" of samples. However, there is one fundamental advantage: optical microscopes make it possible to observe phenomena "live" and thus to understand the unfolding of certain events in real-time—another feature that aligns fluorescence-based optical microscopy more closely with the logic of electronic and television imaging than with that of photographic or cinematographic representation.

Indeed, the productivity of such an imaging tool has not been long coming: for instance, Cortese et al. [9] published in December 2020 a paper resulting from observations conducted with a mixed technique of optical and electron microscopes: they clearly show how the virus induces a complete reorganisation of the infected cells—including endoplasmic reticulum, peroxisomes, mitochondria, the secretory apparatus and the cytoskeleton—to create ideal conditions for its replication.

7.2.4 How the Virus is Made of

In the meantime, a *third* direction of the micro-visual fight against SARS-CoV-2 was looming. Some laboratories were trying to explore and represent the molecular and atomic structure of the virus with increasing accuracy. In part, cryo-EM and cryo-ET make it possible to explore the protein and macromolecular structure of SARS-CoV-2. For instance, in October 2020, the company Nanographics, with the collaboration of Tsinghua University, provided a 3D illustration of SARS-CoV-2 obtained by Cryo-ET, revealing for the first time its structure and detailed architecture [51]. However, more advanced techniques exist, particularly *X-ray Crystallography* (XRC).

In 1912, Max von Laue recorded the diffraction of an X-ray beam by a copper sulphate crystal on a photographic plate; the discovery earned him the Nobel Prize in Physics in 1914. The following year, William Lawrence Bragg and his father,

William Henry Bragg, used the same device to analyse the atomic structure of crystals. Indeed, given the minimum wavelength of X-rays, XRC reaches a resolution of a few ängstroms (the ängstrom is the tenth part of a nanometer: the diameter of an atom ranges between 1.2 and 2.6 ängstroms). They, too, won a Nobel Prize for Physics in 1915. From the 1920s onwards, organic molecules also began to be analysed using the XRC thanks to the possibility of crystallising a sample before analysis (i.e., solidifying it to form a geometrically regular, non-amorphous structure of atoms, molecules or ions in all three spatial dimensions).

At present, XRC is the technique that allows the highest magnification of a sample: starting from the digital information collected and through its further computational processing, it is possible to reconstruct the average position of the atoms (and thus the density of the material) and their chemical bonds. A body of information that is extremely valuable for designing strategies to combat the virus: "This is like getting a high-resolution satellite image of your target. With that information you can best design your attack," comments Dr Gordon Joyce, who uses XRC at the Walter Reed Army Institute of Research (WRAIR), a US Army medical centre (the scientist does not deny the military nature of his institution: [46]).

Once again, the results have been significant, especially in identifying the virus's vulnerability points and the subsequent development of drugs that block its replication. Thanks to the joint work of Cryo-ET and XRC, it has been possible to ascertain the replication mechanism of the SARS-CoV-2 genome (the RNA-dependent RNA polymerase, or RdRp) and thus to develop the first drugs to inhibit this mechanism (in October 2020, the U. S. Food and Drug Administration approved the use of Remdesivir, a drug already used in the fight against the Ebola). Furthermore, XRC has enabled it to work at the protein level, particularly to identify new drugs capable of inhibiting protease, an enzyme indispensable for forming the virus's proteins [31].

And here, where the story of the defeat of SARS-CoV-2 begins, we can stop our account of its micro-visualisation.

7.3 Political Economies of the Visual

7.3.1 Techno-Images and Algo-Images

The history of the "micro-visual" struggle at SARS-CoV-19 opens to different considerations. For instance, following James Elkins [16: 117–155], we might observe how photomicrographic images compel us to rethink the concept of "representation;" or, we can read micrographic devices against the background of the broader category of all "those devices capable of making visible processes that are not in themselves visual—but rather chemical, thermal, magnetic, acoustic, or electrical—thanks to intersubjective performances" [5: 246]; or, we can even consider more specifically how they connect to the broader visual culture of the SARS-CoV-2 [27, 30, 40]. Without leaving these perspectives entirely aside, I will take a somewhat different

approach, leading me to analyse in general terms the uses and role of images in contemporary living environments.

First, let us consider that micrographic imaging has allowed us to grasp, so to speak, "in vitro," the intertwining of two different logics of image production. On the one hand, images are produced and often visualised through the use of flows of electromagnetic energy (light, x-rays, electrons, etc.) which, following different treatments and paths of emission, propagation, condensation, expansion, rarefaction, multiplication, absorption, reflection, refraction, diffraction, come to leave a visual trace on certain surfaces (photographic plates, phosphor screens, electronic sensor grids). We can call this final object a *techno-image* [18]. From a media-archaeological point of view, it represents the oldest sediment, as it is the type of image that characterised modernity: the takeover of light to the electromagnetic spectrum (with Michael Faraday, in 1845) determined its detachment from the optical-geometric dynamics of the previous "classical" regime [50], and at the same time made it the instrument of the constitution of a new type of photographic, cinematographic, electronic image [10, 12, 17: 378–379, 35]. A new kind of micrographic image was also born in this context, organically embedded in the galaxy of modern images [28].

On the other hand, images are produced from a "capture" of electromagnetic fluxes that are transformed into dynamic data structures. These data sets or cubes constitute the image, although they are "invisual" [36]. Thus, the centre of gravity of the process has shifted: it no longer resides in the translation of the real into a stable iconic form, but rather in the automated processes of data extraction and computation, which operate largely independently of any form of visualization. This media-archaeological layer is more recent: it originated with machine vision processes at the end of the 1950s, so that we can call it computational [1] or algorithmic [44] imagery: in analogy with the term "techno-images," I will call them *algo-images*.

7.3.2 Political Iconomies

Second, and from a broader perspective, my story demonstrates that image production, whatever the logic behind it, is always radically connected to a complex but not random network of goals, interests, processes and social dynamics. In this sense, I have repeatedly emphasised the links between the micrographic image and "media" images: photography, cinema, television, and digital media; furthermore, I have observed how the production of the SARS-CoV-2 images was linked to economic investments, reputational returns, time management, the possibility or otherwise of extending the research to poorer countries, the re-use of military research centres, among other factors.

I propose to conceptualise this context as the environment within which the subjects inhabiting it experience and manage different sets of intertwined resources (including the images themselves), sharing their conditioning and affordances. In other words, this environment is characterised by the extraction or production of resources, their circulation and exchange, their transformation and commutation, and

their disposal: all operations capable of modifying the shared environment within which they are conducted more or less in common. Some of these resources (in particular light, pictures, and more recently data) are immediately involved in the production and circulation of images and constitute what Peter Szendy [45] has called an Iconomy; however, they are at the same time intertwined with other sets of resources (raw materials, energy, labour, money, time, reputation, etc.) that need to be considered for a complete view of the phenomena involving images.

I define this perspective of analysis as an (enlarged) political economy approach [14]: in fact, I intend to take up some of the concepts and tools of analysis proper to political economy, i.e. the approach that analyses the strategic and purposive management of resources by given communities [6]; at the same time, however, I consider it appropriate to "de-economise" this approach, i.e. to remove it from a purely market and financial idea of resource exchanges, broadening its application to different fields such as social, ecological, psychological, technological ones. A glance at the story of microvisual research on SARS-CoV-2 immediately suggests that it would be incomprehensible if not framed within a political economy of knowledge and scientific research [49]. Furthermore, many of the details I have highlighted (from the use of forced labour by Siemens to technical expressions such as "photon budget") can be framed and re-read from this point of view.

In essence, the story I reported can also be read as a comparison between two political-economic circuits: the human one, based on cognitive, reputational, financial, technological and visual resources, and the virus one, based on purely biological resources. The two circuits operate on different spatial and temporal scales—and our entire narrative has traced how the human political economy gained access to the viral one. However, a common objective leads both to take control of a portion of the world. And we will have to return to this point in our conclusions.

7.4 Conclusion: The New Political Economy of Light

Let us come back to the distinction between techno-images and algo-images. We can observe that they correspond to two different regimes of the political economy of light, i.e. two different ways of using and exploiting the resource flows offered by the electromagnetic spectrum. On the one hand, the modern regime of techno-images establishes a predominantly *productive* economy by making light the instrument of automated image-making. On the other hand, the contemporary regime of algo-images uses light in a predominantly *extractive* key, as it operates the translation of visual traces into invisual data. In essence, the political economy of light has moved from being at the service of an economy of the visual to being attracted and finally incorporated into the broader galaxy of the data economy.

Yet, my narrative has shown that the two regimes are closely intertwined; it is, therefore, possible and necessary to flank the recognition of their differences with the identification of continuities. Once again, returning to micrographic devices is helpful, as they show that a common purpose determines the connection of

techno-images and algo-images: "grasp the world as picture," according to Martin Heidegger's seminal expression [23: 67]. Techno-images and algo-images both aim at producing informational and operational models of the world, i.e. artificial reproductions that allow for an appropriation of reality both in cognitive terms (design, simulation, identification of patterns and recurrences, prediction of developments, etc.) and in pragmatic ones (transformation of states of affairs in the world based on operations performed with and on them). To pick up on what I was saying above, the political economy on a human scale uses images precisely how the virus uses proteins: that is, as tools for taking possession of and reorganising the world.

In conclusion, the transition from the modern to the contemporary political economy of light does not mark a rupture, but rather an intensification of a long-standing ambition: to transform the world into an image to master it. Algo-images do not *break* with the logic of techno-images—they *radicalise* it. By mobilising vast informational resources and automating cognitive and operational processes, they amplify the mechanisms of visibility and control inaugurated in the modern era. It is within this historical continuum that the rise of what [53] terms "surveillance capitalism" must be situated. Far from being a recent anomaly, it is the latest expression of a visual regime whose roots run deep in the modern project of government through light.

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