Introduction

> For critics and advocates alike, if we want to know algorithms, we may need to live with them.
>
> —Seaver (2013, 11)

Let us start this introduction *in medias res*, in the middle of things:

Rearrangement 1

The election of Donald Trump in November 2016 was quite surprising: how could such a controversial figure reach the White House? The reasons, of course, are innumerous. But what if one of them was Facebook (Lapowsky 2016)? After all, Trump supporters never stopped using this platform to spread out disputed contents. What if voters were brainwashed by the "fake news" Facebook contributed to diffusing? What if this extensive interlinking participated in Trump's advertisement and fundraising? However harsh this claim might be, it seriously harms the image of the web application that would rather help to "connect people" than to build border walls (Isaac 2016). It seems then that monitoring needs to be increased, even though it may contradict some assumptions Mark Zuckerberg elevates as precepts (Zuckerberg 2016). The main target is the "News Feed," the spine of the application that displays stories posted by Facebook users. What about slightly modifying how News Feed automatically selects new stories to make it ignore "low quality posts"? This may help restore Facebook's public image, at least for a little bit, at least for a little while. And after several months of in-house research and testing, a new *algorithm* is made operational that—based on frequencies of posts and URLs of links—identifies spam users and automatically deprioritize the links they share (Isaac and Ember 2016). According to one of Facebook's vice presidents, this new method of computation should significantly reduce the diffusion of "low quality content such as clickbait, sensationalism, and misinformation" (Mosseri 2017).

Rearrangement 2

Planet Mars is a distant location. But hundreds of millions of kilometers did not dishearten the US National Aeronautics and Space Administration (NASA) from sending the robotic rover Curiosity to explore its surface. On May 6, 2012, the costly vehicle safely lands on Gale Crater. Quite a feat! Amazing high-resolution pictures are soon available on NASA's website, showing the world the jagged surface of this cold and arid planet. Of course, Curiosity is far more than a remote-controlled car taking exotic pictures. It is a genuine laboratory on wheels with many high-tech instruments: two cameras for true-color and multispectral imaging, two pairs of monochrome cameras for navigation, a robotic arm with an ultrahigh-definition camera, a laser-induced spectrometer, solar panels, two lithium-ion batteries, and so on (Jet Propulsion Laboratory 2015). Yet there is an obvious cost to this amazing remote-controlled laboratory: it needs to move its 350 kilograms (low gravity considered). The sharp, rocky surface of Mars does not alleviate the constant efforts of Curiosity's wheels, irremediably wearing down. And in January 2014, the situation becomes alarming (Webster 2015): Is there a way to extend the lifetime of Curiosity's wheels? After much research, a new driving *algorithm* becomes operational in June 2017 that uses real-time data from the navigation cameras to adjust Curiosity's speed when it comes to sharp Martian pebbles (Good 2017). By reducing the load of Curiosity's leading and middle wheels up to 20 percent, this new method of computation for navigation is considered a serious boost for the mission (Sharkey 2017).

Rearrangement 3

Israeli secret services in the West Bank are used to dismantling organizations they define as terrorist by means of preventive actions and intimidation. But what about individuals who commit attacks on a whim? Just like several police departments in the United States (Berg 2014), Israeli secret services are now supported by a security software whose *algorithm* generates profiles of potential attackers based on aggregated data posted on social media. Yet while several US civil courts are seriously considering the harmful bias of these new methods of computation (Angwin et al. 2016; Liptak 2017), Israeli military justice as applied to suspected Palestinian "attackers" prevents them from having any sort of legal protection. Thanks to the ability of the West Bank military commander to stamp administrative detentions, these "dangerous profiles" can be sentenced to a renewable six-month incarceration without any possibility of appeal. Many Palestinians targeted by this state-secret technology "have served long years without ever seeing a court" (Gurvitz 2017).

Rearrangement 4

How can people be made to eat more Nutella? It has not been easy these recent years for the Italian brand of chocolate spread. When palm oil production threatened remote orangutans, only a small fraction of citizens was eager to criticize its use in Nutella's recipe. But in May 2016, as soon as palm oil is suspected of speeding up the spread of cancer among Nutella consumers, there starts to be a worrying drop in sales (Landini and Navach 2017). For Nutella, something needs to be done to reconnect with the stomachs of its customers. What about a fresh new marketing campaign? In collaboration with advertising agency Ogilvy & Mather Italia, seven million uniquely designed Nutella jars are soon produced and sold in record time (Nudd 2017). At the heart of this successful marketing move lies an *algorithm* that computes a carefully selected set of colors and figures to generate unique pop patterns (Leadem 2017).

States of affairs change. In November 2016, News Feeds of Facebook users were subjected to spammers diffusing hoaxes and "fake news" that are presumed to have played a role in the election of Donald Trump. One month later, these News Feeds temporarily became monitored lists of stories worth being read. Similarly, Curiosity's weight together with sharp Martian pebbles first seriously affected the robot's wheels, thus compromising the initial duration of the mission. Yet a few years later, several changes in the locomotion system slowed down this unexpected wear. In another case, Israeli secret services were at first powerless against attacks that were not prepared within dismantable cell organizations. Yet these services soon were able to identify suspects and put them in jail without any kind of legal procedure. Finally, Nutella was first an old-fashioned chocolate spread whose recipe included orangutan-endangering and cancer-related palm oil. It then became, temporarily, a trendy pop product. For better or worse, collective configurations are rearranged, thus forming new states of affairs; relationships between humans and nonhumans are reconstituted, thus temporarily establishing new networks. According to this ontological position that is often called "process thought,"[1] the collective world is constantly reshaped in this way.[2]

That being said, we may wish to comprehend some of the dynamics of these messy *rearrangements* (RTs). After all, as we all have to coexist on the same planet, getting a clearer view of what is going on could not hurt; documenting a tiny set of the innumerous relationships that shape the world we inhabit may equip us with some kind of navigational instrument. Together, where do we go? What are we doing? What is going on? These are important, legitimate questions.

To address these questions, two approaches are generally used. Broadly speaking, the first approach consists in postulating the existence of aggregates capable of inducing states of affairs. Depending on academic traditions, such aggregates take different names: they are sometimes called "social forces," "fields and habitus," "economic rationality," or "social structures," among many other variations. These differently named yet a priori postulated aggregates are all pretenders to the definition of the social (or society), an influential yet evanescent matter that supposedly surrounds individuals and orientates their actions. The scientific study of this matter and the states of affairs it engenders is what I call the science of the social or, more succinctly, social science.

The second approach—the one this book embraces—consists in considering the social not as an evanescent matter surrounding individuals but as the small difference produced when two entities come into contact and temporarily *associate* with each other (Latour 2005).[3] This approach assumes that every new connection between two *actants*—humans (Bob, the president, Mark Zuckerberg) or nonhuman entities (a wheel, a virus, a document)—makes a small difference that can, sometimes, be accounted for. If we accept calling "social" the small difference produced when two actants temporally associate with each other, we may call "socio-logy" the activity that consists in producing specialized texts (*logos*) about these associations (*socius*).[4] Our initial four RTs are small examples of such an activity: Facebook, Curiosity, Israeli secret services, and Nutella temporarily associate themselves with new actants, and the blending of these new connections contributes to the formation of new configurations summarized within a text. Had I added several rearrangements and accounted for their constitutive associations a bit more thoroughly, I would have produced a genuine sociological work. On the contrary, had I invoked some hidden force to explain these reconfigurations; had I attributed the modifications of each state of affairs to some a priori postulated aggregate (e.g., economic rationality, society, culture), I would have produced a small work of social science. This distinction between sociology and social science will accompany us throughout this book. It is thus important to keep in mind that the present volume is—or, at least, is intended to be—a sociological work.

With these clarifications in mind, let us have a closer look on our four small sociological RTs. What do we see? We quickly notice that each RT is affected by an "algorithm," for now loosely defined as a *computerized method of calculation*. These four algorithms can be considered entities—or *actants*—as they all produce differences within specific configurations. In that sense, these algorithms are fundamentally not dissimilar to the other actants they, at some point, associate with. In RT1, *there is* Facebook, Donald Trump, spams, supporters, News Feed, a new algorithm, a Facebook vice president, and many other actants that, together, rearrange some state of affairs. In RT2, *there is* Mars, NASA, sharp pebbles, a navigational algorithm, lithium-ion batteries, and many other actants that, together, rearrange some state of affairs. The same is true of RT3 and RT4: algorithms are actants among many other actants.

Yet a closer look nonetheless suggests that the algorithms of our RTs possess characteristics that make them not completely akin to, say, sharp Martian pebbles or lithium-ions batteries. Contrary to such "firm" actants, the algorithms of our RTs appear more fluid; they seem to be able to move very quickly and make connections with other actants that were at first remote from each other. In RT1, Facebook's new algorithm can, in the end (and yet temporarily), associate itself with News Feeds of millions of users located all around the world almost instantaneously. In RT2, NASA's algorithm can reach Mars to make Curiosity's wheels cope with, potentially, all sharp Martian pebbles. In RT3, the algorithm used by Israeli secret services can classify thousands of social media texts sent by hundreds of thousand people located throughout a two-thousand square-mile territory. In RT4, Ogilvy & Mather Italia's algorithm can create millions of uniquely designed patterns instructing Nutella's packaging factories in Italy and France. It seems then that these algorithms can circulate and link up initially sparse actants in a very short amount of time. This is a nontrivial characteristic. To underline these algorithms' fluidity (they circulate), swiftness (they are fast), and distributivity (they are simultaneously scattered and united), let us temporarily categorize them as *devices*, a special category of actant that, according to philosopher Gilles Deleuze, is "tangled, multi-linear ensembles [that] trace processes that are always at disequilibrium, sometimes coming close to each other, sometimes getting distant from each other" (Deleuze 1989, 185).

If we continue considering our four RTs, we also quickly notice that each of these fluid, swift, and distributed devices called algorithms contributes to modifying a network of relationships. In every RT, one algorithm—well supported by many other entities (researchers, data, tests, computers, etc.)—participates in making Facebook less subject to the spread of hoaxes (RT1), Curiosity's wheels a bit more durable (RT2), Palestinians definitely more "jailable" (RT3), and Nutella temporarily more salable (RT4). Along with all the entities they are associated with, these methods of calculation seem then to participate in changing power dynamics: Facebook, Curiosity's wheels, Israeli security services, and Nutella become temporarily *stronger* than Trump-spamming supporters, sharp Martian pebbles, West Bank potential "terrorists," and palm oil scandals, respectively.

Scholars of *Science and Technology Studies* (STS)—a subfield of sociology and social science that aims to document the co-constitution of science, technology, and the collective world[5]—are nowadays prone to analyze algorithms' propensity to modify power dynamics in, for example, labor markets (Kushner 2013; Steiner 2012), surveillance strategies (Introna 2016; Introna and Wood 2002; Kraemer, van Overveld, and Peterson 2010), corporate finance (Lenglet 2011; MacKenzie 2014; Muniesa 2011a), cultural habits (Anderson 2011; Hallinan and Striphas 2014), or interpersonal relationships (Beer 2009; Bucher 2012). These scholars' works are of the most importance as they raise and maintain wakefulness with regard to what computerized methods of calculation do. Yet I must warn the reader right from the start: what algorithms do is not the main topic of this book.

However, as soon as one takes seriously into consideration the banal fact that objects and devices wear down and change, that "they break, malfunction and have to be constantly mended, retrofitted and repurposed" (Domínguez Rubio 2016, 60), thorough sociological studies of what algorithms do should be coupled with the studies of the maintenance and repair work required to keep them doing what they do. Whereas maintenance and repair work is currently receiving the attention of an increasing number of studies (e.g., de la Bellacasa 2011; Domínguez Rubio 2014, 2016; Denis and Pontille 2015; Lea and Pholeros 2010; Strebel, Bovet, and Sormani 2018), very few have specifically explored the work required to keep algorithms doing what they do (but see Crooks 2019). It is a shame since the differences algorithms produce should be, at least in principle, proportional to the work required to make them continue to produce such differences in constantly evolving situations. If we continue to draw upon our four initial RTs, we can for example imagine that to keep on protecting users from spammers, Facebook's new monitoring algorithm may need to be actualized to detect unexpected forms of trolling (RT1). Similarly, if Curiosity's balance of weight happens to change—such as if it loses a piece of equipment—the parameters of its driving algorithm will have to be modified (RT2). In a similar vein, due to the progressive accumulation of small differences in the computer equipment of Israeli secret services, the software package allowing the new security algorithm to effectively compute social media data and generate profiles will have to be slightly updated (RT3). Finally, for its algorithm to keep on supporting effective marketing *coups*, Ogilvy & Mather Italia will need to keep on convincing its clients that consumers are attached to singular products (RT4). In short, we can make the fair assumption that without constant efforts to make algorithms keep on fitting with constantly changing situations (and vice versa), these devices will not produce differences for very long. Although the work necessary to preserve the *agency* of algorithms (Introna 2016) is surely more and more common in contemporary economies, it remains poorly documented. Unfortunately, I will not contribute to filling in this gap; despite the need for such studies to better understand the collective world we live in, this book does not deal with the maintenance of algorithms.

What is this book's topic, then? We have quickly seen that, from a sociological standpoint, algorithms can be considered two kinds of entities: devices that *do* things and devices that *need* things in order to keep on doing what they do. Both views are, I believe, of great significance. Yet my work follows a different path. Instead of starting from algorithms as devices and studying their agency or need for maintenance, this book starts from unrelated entities (e.g., documents, people, desires) and tries to account for how they come into contact to form, in the end, devices we may call "algorithms." In short, I am studying what is happening *before* algorithms become fluid, swift, and distributed devices. Of course, things are not so clear-cut; as we will see, projections on both agency and maintenance requirements of future algorithms may impact on their constructions. Moreover, already constructed algorithms participate in the formation of new algorithms. But still, it is important for the reader to understand that I will mainly inquire into the practical activities by which algorithms are progressively assembled in assignable locations rather than what they may suggest or require once they are assembled.

Negative Invisibilities

Already at this point, a question may arise: Why is it important to account for the formation processes of algorithms? Why spending time and energy writing—and reading—about their constitution? Are there not other things to do than making the activities by which algorithms come into existence visible?

Certainly. As Star and Strauss (1999) have suggested, some activities need to remain provisionally invisible—that is, not accounted for—otherwise the results of these activities may lose some of their capacities. The circus is one example: making publicly visible the infrastructure and training practices required to design and master, say, a Cirque du Soleil trapeze act may negatively affect the act itself. Wonder, surprise, or enchantment would potentially be counteracted by the down-to-earth and uncertain operations that enabled the act. Here, a sociological account would take the risk of spoiling the act; it may lower the act's *capacity to act*.[6] Following the distinction made by Star and Strauss (1999, 23), the relative invisibility of the trapeze act is, in that sense, *positive*: it helps the product of these circus practices to be, by lack of a better term, adequate. The lack of any publicly available account and the presence of secrecy help the act become an act, just as they help the public become the public of the act. In such a very specific situation, one may assume there is a mutual desire to believe in mastery.

But as soon as there are controversies about the products of some practices, the terms of their adequacy are disputed; when some capacity to act is put into question, disagreements about its formation need to be confronted. Let us, for example, imagine that the same Cirque du Soleil trapeze act leads to an accident. If disputes arise about this accident, there will be requests to make visible the practices that contributed to producing it. From being positively invisible, the practices required to do this trapeze act would become negatively invisible: for the different parties of the dispute to become able to *negotiate*, empirical accounts of how this act comes into existence will become necessary. What does the Cirque du Soleil need to perform this controversial act? Which elements could be changed to readjust this fragile assemblage? In short, in order to propose *compromises*, in order to better *compose*, disputants will benefit from empirical accounts of the practices of trapeze;[7] documenting what performers and entertainers cherish and fear and what they are attached to might allow constructive dissensions about the agency of what they produce to unfold.

Despite its obvious limits, this small imaginary example indicates that the request for visibility is somewhat correlated with the rise of controversies. When there are controversies over the products of practices, these products cannot be considered adequate anymore: positive invisibilities may thus switch to negative invisibilities that themselves call for empirical accounts—which can take the form of sociological investigations—on which disputes may arise *and* negotiations unfold. Of course, these accounts are very risky as they inherently speak in the name of individuals (Latour 2005, 121–140). To make visible what communities of practice need and cherish, and what they are attached to, the sociological account that may establish common grounds for further contentious negotiations would need to overcome many trials: Does the account make visible the actants that are crucial to the work of the practitioners? Do surprising but empirically supported connections unfold? Does the account propose new grips for collective composition? A single "no" to any one of these questions would make the sociological account fail to fulfill its initial commitment.

What about algorithms? Not so long ago, these devices attracted little attention. They were certainly involved in changing power relations, but these processes were not, or only to a limited extent, public issues. Things began to change in the late 1990s when sociologists started to question the discourse on empowerment and information accessibility put forward by the promoters of web technologies.[8] Hoffman and Novak (1998) showed, for example, that the accessibility and use of web technologies in the United States were largely function of racial differences. Lawrence and Giles (1999) stressed that, contrary to the promotional rhetoric of almost unlimited access, the search engines available in the late 1990s were only able to index a small and oriented fraction of the web. In the same vein, Introna and Nissenbaum (2000) underlined the underground—and potentially harmful—influence of the heuristics used for the classification of URLs by these same late-1990s search engines. The post-9/11 period that followed focused on criticisms of biases in programs and *algorithms*—the term appeared at that time in the critical literature[9]—for surveillance and preventive detection. In his study of the social implications of data mining technologies, Gandy (2002) warned, for example, that they are the gateway to rational discrimination, potentially strengthening correlative habits between social status and group membership. From a political economy perspective, Zureik and Hindle (2004) discussed biometric algorithms' propensity to trivialize social profiling, categorization, and exclusion of national groups. Another example is the work of Introna and Wood (2004): their analysis of facial recognition algorithms highlighted the potential biases of these devices, which were often, at that time, presented as impartial. This line of sociological research led, at the beginning of the 2010s, to numerous investigations on discriminations (e.g., Kraemer, van Overveld, and Peterson 2010; Gillepsie 2014 Steiner 2012) and invisibilizations (Bucher 2012; Bozdag 2013) induced by the use of algorithms.

This research direction has continued in recent years, with increasingly comprehensive works revealing the contrasting, and often questionable, effects of algorithms on contemporary societies (e.g., Crawford and Calo 2016; Noble 2018; O'Neil 2016; Pasquale 2015). These awareness-raising efforts were also reported in the press, further making algorithms matters of public concern (e.g., Mazzotti 2017; Risen and Poitras 2017; Smith 2018). This dynamic—too complex to be thoroughly dealt with in this introduction[10]—has led to the current situation where the collective world is steadily affected by controversies over algorithms. A quick look at the news, at the time of writing, suffices to remind us of it. UK police is about to use a new algorithm to identify online hate crime on social media (Roberts 2017)? This soon triggers hostile reactions from the nonprofit organization "Big Brother Watch," ready to "fight any attempt to curb free speech online" (Parker 2018). A new algorithm is published in an academic journal that can presumably deduce people's sexuality from photographs of faces (Levin 2017)? The Gay & Lesbian Alliance Against Defamation soon condemns such a "dangerous and flawed research that could cause harm to LGBTQ people around the world" (Anderson 2017).[11] Facebook's algorithm continues to bombard a grieved woman by parenting ads after the stillbirth of her son (Brockell 2018)? Thousands of tweets soon denounce gender bias from tech companies (Mahdawi 2018). Every week, a new dispute arises regarding the consequences—actual or potential—of new algorithms, often preceded by changing attributive nouns such as big data, machine learning, or more recently, artificial intelligence.

The intended relevance of this book should be considered in the light of the current controversies over the agency of algorithms. Following in the footsteps of authors such as Bechman and Bowker (2019), Barocas and Selbst (2016), and Grosman and Reigeluth (2019)—to whom I shall return later in the book—my aim here is to propose intellectual tools to prepare the elaboration of compromises. The invisibility of the practices underlying the development of algorithms can indeed no longer be considered positive: as they are the object of repeated disputes, it is now certainly important, or at least interesting, to document the practical processes that enable them to come into existence. Roughly put, if sociology has looked, with a certain success, at the effects of algorithms, it is now time for it to inquire into the *causes of these effects*, however distributed and multiple they may be. A gap needs to be filled in; by means of empirical accounts of how computer scientists and engineers nurture algorithms, some risky yet refreshing grounds for constructive disputes may be provided.[12] The needs, attachments, and values of those who design algorithms—as documented by my limited sociological account—may contradict other needs, attachments, and values. But at least, in these days of controversies, parties in dispute may slowly start to negotiate, as Walter Lippmann says, "under their own colors" (1982, 91). Yet before considering how I intend to effectively run this inquiry into the practical formation of algorithms, I quickly need to further specify its political dimension. To do so, I shall now make a quick detour by discussing the unconventional term "constitution" I use here to qualify my venture.

Why "Constitution" (And Not Simply "Construction")?

At the beginning of this introduction, I asserted that the collective world is constantly rearranged: heterogeneous entities never stop associating with each other, the blending of these associations temporarily establishing new states of affairs. From this (debatable) ontological position, it follows that the world is not "out there," ready to be grasped from some outside standpoint. Instead, according to this processual ontology, the world is always *becoming*; it is the active product of associations between human and nonhuman actants.

Yet one may rightly argue that everything is not always reinvented. While some associations bring about ephemeral actants (e.g., a cry of joy, tears of sadness, laughs at some joke), some other associations bring about actants that are more enduring. Many entities that populate/generate the collective world are of this sort: Mark Zuckerberg, the planet Mars, West Bank jails, Nutella jars—just to mention some entities we encountered in our small initial RTs—are quite enduring entities. Such actants, thanks to their ability to live on beyond the here and now of their instantiation, may in turn associate themselves with other actants, thus contributing to the continuous generation of the collective world. Such relatively stable actants possess some *durability* that allows them to bring about and orient what is becoming.

If we continue considering differences among actants, we quickly notice that some durable actants can *move* from one place to another more or less easily. Let us keep on using familiar entities to illustrate this point. If we consider the planet Mars and West Bank jails, these entities appear rather static. It is difficult for them to associate with actants capable of making them deviate from their initial trajectories: without important mobilization efforts, the planet Mars and West Bank jails will just stay where they are. This is not quite the case for Mark Zuckerberg who, once associated with actants such as "shoes," "cars," or "roads," can markedly change his initial trajectory and, in turn, associate himself with other actants that were at first distant from him. Yet, largely due to his body envelope, Mark Zuckerberg's relative mobility is rather costly: in order for him to somehow keep on being Mark Zuckerberg, in order for him to maintain most of his durability while he is moving, he would need to associate with many other actants (e.g., oxygen, food, space for his legs, coffee breaks) protecting him from being too much altered. In the case of Nutella jars, the story is a bit different. They too need to associate with other actants to deviate from their initial trajectories (e.g., supply chain managers, railway lines, sale contracts, delivery people). But contrary to Mark Zuckerberg, one can make the fair assumption that Nutella jars' alteration is slower: due to their proper materiality, due to their own *medium*, they can, for example, be stored, piled up, and handled without being significantly transformed. Among our exemplary durable entities, Nutella jars seem then the most durable *and* mobile: when compared to the planet Mars, West Bank jails, or even Mark Zuckerberg—and when provided adequate associations—these jars can move from one place to another without being too much altered.

When cumulated, durability and mobility are nontrivial characteristics: entities that combine both abilities are more likely to associate with other entities, thus actively contributing to the generation of the collective world. But a very special category of entities cumulates another ability that makes them certainly the most world-generative of all. These entities go by different names: Jack Goody calls them "graphical objects" (1977); Bruno Latour and Steve Woolgar call them "inscriptions" (1986, 43–91); Dorothy Smith calls them "accounts" or "documents" (1974). But no matter how these are labeled, sociologists have long emphasized on these actants' fascinating capacity to be durable and mobile *and* to carry with them some characteristics of other actants—or of other associations between actants. This is essentially what texts, tables, graphs, or drawings do: thanks to the presence and constant maintenance of specific habits, rules, and technologies—what Jérôme Denis (2018) calls *scriptural infrastructures*—these often durable and mobile inscriptions can host some aspects of actants and associations and present them *again* (*re*-present) somewhere else. This scriptural transport of (part of) actants—that itself necessitates many other actants to unfold—may in turn create a link between what has happened and what is to become. This sounds like an odd statement, but such a phenomenon is in fact very common: Every time I read a *New York Times* article, a connection is made between what has happened in the past (some events) and what is happening now (me, considering this event and, eventually, reacting to it). Of course, this connection, this link has been formatted in order to be hosted in the specific materiality of the inscription I am considering (here, the newspaper article). Such a link is thus always a partial, but potentially faithful, in-formed version of what has happened. When I'm reading the *New York Times*, I don't see migrants struggling to reach

Europe in horrendous conditions; I see a flat surface with words that re-present me those migrants; this re-presentation triggering in me feelings of helplessness, shame, and despair, evanescent actants that will, in turn, contribute to the continuous generation of the collective world (though quite insignificantly). To qualify inscriptions' capacity to carry some properties of actants-associations and establish formatted yet generative connections between times and locations, I shall use the term "re-presentability." More than just being durable and mobile actants, inscriptions are thus also re-present*able*: they can—together with suitable infrastructures—carry, transport, and display properties that are not only theirs.

Durability, mobility, re-presentability: these are capacities not to be underestimated. Inscriptions, despite their often-modest appearances (lists of numbers, drawings, articles, tables, graphs), greatly participate in the shaping of our world. A new molecule appears that revolutionizes our understanding of the human hypothalamus? As well documented by Latour and Woolgar (1986), such an association-prone actant derives, to a large extent, from inscriptions assembled, accumulated, compiled, and compared within and between laboratories. A new management technique starts to align corporate activities to a single arbitrary standard? As proposed by Thévenot (1984) and Yates (1989), such Taylorist normalization—and its consequences—heavily relies on measures, coding, and equity methods whose scriptural circulation allows the centralization of control over the workers. A new algorithm is published that may ignite original avenues of research in digital image processing? As I will try to show throughout this book, the formation of such an actant owes a great deal to the production, circulation, transformation, and compilation of many different types of inscriptions. We will more thoroughly examine the world-generative capacity of inscriptions in due time (especially in chapters 4, 5, and 6). For now, suffice it to say that these durable, mobile, and re-presentable actants contribute *a lot* to what is constantly happening.

But whatever their generative power, "inscriptions" do not exist by themselves: they obviously need to be produced before they start to circulate. In that sense, every inscription needs to be *inscribed*. Extracting some aspects of associations (or "events"; at this point, both terms are equivalent) and re-presenting them on flat, durable media is not at all evident: What part of the event shall be kept and written down? What language shall be used? What protocol shall be followed to later compare this inscription with some others and produce, in turn, new compiled inscriptions? Considering the world-generative potential of inscriptions, these are major issues, most of time supported by organizational and professional practices with their own goals, rules, and principles that every day engage hundreds of millions of people and instruments. This oriented work consisting in producing inscriptions and, eventually, capitalizing on their world-generative potential is what Dorothy Smith (1974) calls "the fabric of documentary reality."[13] And this fabric is highly political.

To illustrate her point, Smith takes the a priori mundane example of birth certificates. Inscribing a birth on a report is, in fact, not evident nor neutral. It is the product of an organizational and professional practice that shapes births and their accounts in very peculiar terms, very different from, say, how mothers and fathers may want to remember it. As she put it:

> "Jessie Franck was born on July 9th, 1963" appears maximally unequivocal in this respect. But as we examine how it has been fabricated it becomes apparent that its character as merely a record is part of how it has been contrived. Everything that a mother and a father might want to have remembered as how the birth of Jessie Franck was for them is stored elsewhere and is specifically discarded as irrelevant in the practices of the recording agency. The latter is concerned only to set up a certified and permanent link between the birth of a particular individual—an actual event, and a name and certain social coordinates essential to locating that individual—the names of her parents, where she was born, etc. (Smith 1974, 264)

Birth certificates are very selective—they only keep a very small part of birth events—and this selection is oriented toward the potential of such concise inscriptions—their features can, in turn, be used for identification purposes or government statistics. Moreover, as being inscriptions that can be remobilized in other spaces, birth certificates and their desired purposes make a specific version of births that will, in many cases, impose on other concurrent versions. Despite their very partial and partisan origins, these circulating inscriptions will form a fulcrum for other inscriptions, progressively establishing formal, factual, and so-called "neutral" versions of births.

This political aspect of inscription practices which aim to make partial partisan versions of events does not only concern administration. The power of Smith's argument lies in that it is also applicable to *any* inscription as it is materially impossible to fully inscribe an event in all its subtleties: choices need to be made regarding what will be kept (and formatted) and what will be ignored. What inscriptions gain as world-generators also lose as world-betrayers, the latter being even a condition to the former.[14]

With these elements in mind, let us now come back to this present book. Have I not said it intends to be a sociological work? Have I not said it intends to account for associations that progressively form devices we call algorithms? At this point, these assertions can be further specified. Sociology, as a professional activity that consists in producing specialized texts (*logos*) about associations (*socius*), does not escape what I shall now call "Dorothy Smith's law": however descriptive it is, sociology brings into being—by means of inscriptions—partial realities to the detriment of other realities. What is true for administrators (Desrosières 2010), economists (MacKenzie, Muniesa, and Siu 2007), or scientists (Latour 1987) is also true for sociologists: while describing realities by means of texts, they also enact these realities.

As Law and Urry (2004, 396) well summarized it, *there is no innocence*:[15] a text, however faithful—and some texts are definitely more faithful than others—is also a wishful accomplishment. I must then admit that what I intend to do in this book is not only describing what happens in particular, algorithm-related, situations: due to this book's very existence as a textual inscription, it is also an attempt at enacting a world to the detriment of other enacted worlds. My gesture is thus analytical and political: it aims to produce a descriptive account of how algorithms come into existence—we can keep that—*but also*, and in the same movement, to propose a new version of their realities. The motivation behind this analytico-political move were presented in the previous section: in these days of controversies over the agency of algorithms, a refined—yet formatted and thus intrinsically limited—account of their inner components may establish grounds for constructive disputes about and with algorithms.

To come back to the title of this section, I assume the classical notion of "construction" does not well express such a venture. Construction has been for sure a useful term for sociology as it has equipped many valuable critiques of naturalized matters: studies on the construction of gender (Lorber and Farrell 1991), patriarchy (Lerner 1986), or maternity (Badinter 1981), just to mention some classics, have all been wonderfully liberating. But considering recent developments in STS and sociology in general, it appears that construction suffers from being two-faced: while it well expresses its descriptive aspirations—showing how results have been produced—it also tends to hide its political claims—generating realities to the detriment of others.[16] Due to its propensity to hide "Dorothy Smith's law" under the cover of analytical ambitions, I consider it wiser to renounce using the term "construction" to qualify my overall gesture.

I am not the first sociologist to dismiss construction. It is in fact quite a popular move, motivated by more or less the same arguments as presented above. Law and Urry (2004) prefer to use "enactment" as it better expresses the performativity of descriptive ventures. Latour (2013), inspired by Souriau ([1943] 2015), has recourse to "instauration" as it underlines the fragility of practical, succeeding assemblages. Ingold (2014), in the wake of Rorty (1980), gives priority to "edification" as it stresses the continuous and never fully achieved aspect of what is about to happen. All these notions are surely interesting alternatives to construction. But at the risk of feeding in a sociological jargon already well supplied, I choose here to use the notion of "constitution" as it has the significant advantage of containing natively a double signification: a *process* by which something occurs as well as a *document* advocating for rights and prerogatives. Here lies an interesting tension that may recall the assumed ambivalence of my gesture: describing and contesting. Moreover, as a constitution is never fixed once and for all (it can be amended, completed, abolished), the notion forces us to recognize the necessary incompleteness of my venture, the three activities that I try to put into existence here—ground-truthing, programming, and formulating (more on this later, obviously)—must be considered partial and temporary. Many more gerund articles, as long as they are supported by empirical materials, can be potentially added to the present constituent act of algorithms.

For all these reasons, this book's title *The Constitution of Algorithms* should be understood as the putting into text and existence—simultaneously empirical and activist—of what algorithms *shall be*. At the very end of the inquiry, in light of the accounted elements, I will come back to the implications of this analytical/insurrectional gesture in a section borrowing from Antonio Negri's (1999) work on "constituent power." For now, let us just note and accept this ambivalence by using the term constitution, a constant reminder of this inquiry's bipolarity.

A Laboratory Study

At this point, I have no other choice than to ask the reader to follow me—at least temporarily—in assuming that in these days of controversies over the agency of algorithms, the invisibility of the work required to design, shape, and diffuse them is negative as it prevents disputing parties from having common grounds for negotiations. Let us also assume that one way to propose such grounds, and thus to suggest constructive disputes and composition attempts, could be to conduct sociological inquiries in order to make visible the work practices required to make algorithms come into existence. Let us finally assume that this volume is an attempt at such an inquiry that, in its capacity as a world-generative inscription, cannot but be a partial, partisan, and open-ended (while also faithful and empirical) constitution of algorithms. If we accept these debatable assumptions, the next question could be: How can I effectively run such a partial, empirical, and activist inquiry? On what materials can I ground it?

It would be tempting to use readily available sources, such as the many academic papers and manuals describing the internal workings of algorithms. This is in fact what several STS scholars have done in some very interesting works.[17] However, I have reasons to believe that the sole use of these sources surreptitiously contributes to the perpetuation of the negative invisibility of algorithms' components. Regarding computer science papers published in academic journals, it would, of course, be incorrect to say that this literature is erroneous: on the contrary, it attests to what is about to, perhaps, become scientifically true.[18] But as many important science studies have shown, these scientific publications tend to report the results of processes, not the practical activities that led to those results. Under these conditions, it is problematic to solely use academic publications to make the formation of algorithms visible since these documents are themselves supported and framed by unstated elements. Michael Lynch (1985) well summarized this problem inherent in the analysis of scientific publications:

> [Methods sections of scientific research papers] supply step-by-step maxims of conduct for the already competent practitioner to assimilate within an indefinite mix of common sense and unformulated, but specifically scientific, practices of inquiry. These unformulated practices are necessarily omitted from the domain of study when science studies rely upon the literary residues of laboratory inquiry as the observable and analyzable presence of scientific work. (Lynch 1985, 3)

Moreover, for entangled reasons we will cover throughout this book, authors of academic papers tend also to *defend* their algorithms against concurrent algorithms. A claim published in a scientific journal is indeed directed against other claims and is intended to obtain the reader's support. Hence the importance of captation techniques that aim "to lay out the text so that wherever the reader is there is only one way to go" (Latour 1987, 57). These conviction habits and the additional necessity they provide—essential elements to establish objective constructions—tend to *purify* the scientific accounts of algorithms of the many disparate elements that have contributed to their textual existence. When relying on these documents to analyze computerized methods of calculation, it is therefore the hesitations, doubts, and "infra-ordinary" equipment and writings that tend to escape the analyst's gaze.[19]

But what about the numerous manuals that teach us how to design algorithms?[20] Do they not provide descriptions of how to assemble computerized methods of calculation? Are they not, in that sense, *connectors* between algorithms and the collective world they contribute to shaping? These pedagogical resources are certainly crucial to inculcate students and newcomers with the basic components of computerized methods of calculation, which are essential to their sociological analysis. Yet, as Lucy Suchman (1995) reminded us, these resources are, by definition, normative accounts of how work should be done, not of how work is effectively done. This is a crucial but often forgotten precision: "[These] normative accounts represent idealization and typifications. As such, they depend for their writing on the deletion of contingencies and differences" (Suchman 1995, 61). Instead of accounting for what it is being done during mundane situations, manuals account for what ought to be done. They are (important) peremptory recipes, not empirically grounded accounts of practices.[21] This is, I believe, the main limitation of contemporary studies that rely mainly upon textbooks and classes on algorithmic design: they inform about how contemporary pedagogues want algorithms to be constructed, not on how these algorithms are constructed on a day-to-day basis. Instead of getting closer to computer scientists by accounting for their work, these studies, otherwise very interesting, tend to move them further away.[22]

Academic papers and manuals are therefore sources that should be handled with precautions. But how to reach what these sources, which remain useful and important, contribute to keeping out of sight? How to get a higher definition, yet still intrinsically limited, picture of the work required to assemble algorithms? Fortunately, for this very specific purpose, I can rely on a proven STS analytical genre often labeled "laboratory study." The first such studies appeared in the 1970s, mostly in the United States. In a sense, the collective (Western) world was at that time not so dissimilar to the one we are experiencing today: controversies about types of agencies were arising continuously. But instead of algorithms, these controversies mostly concerned *scientific facts* often developed in life science, physics, and neurology. For many reasons that are too entangled to be discussed in this introduction,[23] several scholars felt the need to deflate the delusive aspect of scientific facts by sociologically accounting for mundane practices of natural scientists trying to *manufacture* certified knowledge (Collins 1975; Knorr-Cetina 1981; Lynch 1985; Latour and Woolgar 1986). The method of these scholars was quite radical: in reaction to the authoritative precepts of epistemology, these authors borrowed from ethnography its *in situ* analytical perspective to document "the soft underbelly of science" (Edge 1976). As Latour and Woolgar put it:

> We envisaged a research procedure analogous with that of an intrepid explorer of the Ivory Coast, who, having studied the belief system or material production of "savage minds" by living with tribesmen, sharing their hardship and almost becoming one of them, eventually returns with a body of observations which he can present as a preliminary research report. … We attach particular importance to the collection and description of observations of scientific activity obtained in *a particular setting*. (1986, 28; emphasis in the original)

Instead of starting from scientific theories, minds, or "laws of Reason," these laboratory ethnographers—who actively participated in the launching of *Science and Technology Studies*—decided to start from mundane actions and work practices to document and make visible how scientific facts were progressively assembled. Several other monographs accounting for the practices of physicists (Traweek 1992; Sormani 2014) and design engineers (Vinck 2003) followed the seminal 1980s laboratory studies, each time providing insightful new results. We will cover some of these results in due time. For now, suffice it to say that the present sociological inquiry is based almost entirely on these works. But what does that concretely imply?

It first implies locating places where individuals work daily to assemble algorithms. For my case, this localization exercise was not very difficult as I was institutionally close to a European technical institute with about twenty computer science laboratories working every day to propose new algorithms and to make them circulate in broader academic and industrial networks. A more arduous task was to convince the director of one these laboratories to let me describe the practical shaping of algorithms as an "intrepid explorer." Fortunately, institutional movements related to the establishment of a new institute of digital humanities enabled me to share my research ambitions with a computer science professor open to interdisciplinarity.[24] And after several trials, I could be part of her laboratory of digital image processing for two and half years, from November 2013 to March 2016. These were no passive moments: as required by the analytical genre of laboratory studies and also by the rules of the laboratory to which I was affiliated as full member, I had to participate in the life of the laboratory and thus become somewhat competent. Although the skills I progressively acquired certainly did not make me become a computer scientist, they were nonetheless crucial for speaking adequately about issues that mattered to my new colleagues. But participating and discussing were not enough: I also had to write down, collect, and compile what I did, saw, and discussed. Very concretely, this implied taking *a lot* of notes. Discussions, meetings, presentations, actions: everything I experienced had, ideally, to be written down, referenced in notebooks and computer documents to be later retrieved, compared, sampled, and analyzed. This full-time data compilation work implied one last move: after my stay within the computer science laboratory—during which I participated in projects, held discussions with colleagues, observed what they did, wrote down as much as I could, and made presentations about my preliminary results (processes that have deeply transformed me and the sociology I now do)—I had to return to my own community of research to more thoroughly work on the collected materials and write an investigation report that, progressively, has become the present book.

But these all-too-basic elements—that will be more thoroughly presented in chapter 1—elude one important question: How to effectively account for, and thus write down and analyze, what computer scientists do as they try to shape new algorithms within their laboratory? How to experience, capture, and analyze their *actions*?

Courses of Action

As soon as one is convinced of, and enabled to, undertake a laboratory study to document—in a partial yet faithful way—the constitution of algorithms, one quickly lands in uncharted territory. If there are laboratory studies of life sciences, physics, medicine, or brain sciences, very little has been published on computer science work.[25] The cost of entry and the time required to carry out this type of investigation certainly contributed to this situation. But it is also possible that a peculiar habit of thought participated in this disinterest. Indeed, for entangled reasons I will try to tackle in chapters 3 and 5, the fair assumption that computer code and mathematics actively contribute to the shaping of computerized methods of calculation is often doubled with the not-so-fair assumption that both code and mathematics have no, or little, empirical thickness. This assumed evanescence of the ingredients of algorithms contributes, in turn, to making them appear inscrutable. This common habit—that Ziewitz (2016) associated with an "algorithmic drama"[26]—may have discouraged sociologists from entering sites where algorithms are shaped, diffused, and maintained: Why bother trying to inquire into these places since everything happens in the heads of those who work there?

But like any ethnographer involved in the daily work of a scientific laboratory—trying to participate, talk adequately, and compile empirical materials—I quickly realized that very few things could be attributed to the brains of my colleagues, however clever they were. Of course, they never stopped doing things—writing on scratch paper, comparing graphs, typing on keyboards, inspecting databases, moving their mouse cursors, taking coffee breaks—that at first appeared unrelated. But as I stubbornly accounted for these things in my logbooks, I soon realized that the succession of these small elementary "blocks" of action sometimes ended up forming bigger accomplishments: a database, a script, a complete program, an algorithm. By remaining continuously with my new colleagues in their laboratory, conscientiously writing down observations and even recording some work sequences (with their prior authorization), I was soon forced to admit that what we call "practice" is in fact *a term without opposite* (Latour 1996). In the artificial setting of my laboratory study, accounting for as many associations as possible, I soon realized that the much-debated distinction between "theory" and "practice" was an artifact. In the laboratory, there were only practices whose *successions* ended up sometimes forming "databases," "computer programs," "mathematical models," or "algorithms." A little-equipped retrospective look on these trajectories could easily ignore their importance. But once I managed to slow these trajectories down and patiently account for them—sometimes with the help of those who were realizing them—I realized that I could almost do without any internal "abstract" cognitive mechanisms.

Following the seminal work of Jacques Theureau (2003), I shall use the term *courses of action* for these accountable chronological sequences of gestures, looks, speeches, movements, and interactions between humans and nonhumans whose articulations may end up producing *something* (a piece of steel, a plank, a court decision, an algorithm, etc.).[27] Sticking to this generic definition is crucial as it will help us resist the supposed abstraction of computer science work: what ends up being called a "mathematical model," "code," or even "algorithm" must be, one way or another, the product of accountable courses of action unfolding within specific situations and carried out by assignable actants. Moreover, I shall include under the generic term "activity" courses of action unfolding in different times and locations that yet lead to related achievements. In this volume, an activity will then be understood as *a set of intertwining courses of actions sharing common finalities*. The three parts of this volume are all adventurous attempts to present activities taking part to the formation of algorithms; hence their respective titles ending with *ing*: ground-truth*ing*, programm*ing*, formulat*ing*.

This leads to one potential limitation of courses of action as laboratory studies allow them to be accounted for. I mentioned earlier that trajectories must often be slowed down to identify the courses of action whose articulation may lead to the formation of something. This slowing down is salutary as it allows many crucial shaping actions to unfold. But it also has one flaw: it forces one to proceed *very* slowly. As a consequence, any small a priori mundane course of action may unfold on a dozen pages, thus limiting the number of cases.[28]

Three Gerund Parts (But Potentially More)

I hope the reader has gotten a sense of why I decided to make this inquiry, how I tried to conduct it, and where it may eventually lead. But before diving in this exploratory study, I shall briefly present the three parts of this book that, following my action-oriented methodology, are all gerunds: ground-truthing, programming, formulating.

Part I mainly deals with the work required to define problems capable of being solved computationally. In chapter 1, I present the overall setting of the inquiry and introduce basic notions in digital image processing and standard algorithmic study. In chapter 2, I go directly to the heart of the matter and follow a group of young computer scientists trying to publish one of their algorithms. During this first case study of image processing in the making, we will encounter what computer scientists call "ground truths": referential repositories that work as material bases for algorithms. The centrality of ground truths and of the work required to build them make me assert that, to a certain extent, *we get the algorithms of our ground truths*.

Part II tries something that has rarely been attempted: considering computer programming as a practical, situated activity. In chapter 3, I propose historical and conceptual reasons why programming has resisted—and still resists—ethnographic scrutiny. At the end of the chapter, I focus on the computational metaphor of the mind, the main conceptual stumbling stone preventing any close analysis of computer programming practices. In chapter 4, building on notions and concepts introduced in the previous chapters, I carefully describe computer programming courses of action I attended during my laboratory study. Besides opening new avenues of research, this second case study leads, inter alia, to the following proposition: *a programmer may never solve any problem*.

In part III, I consider the role of mathematics in the formation of algorithms. In chapter 5, I first build on STS-inspired inquiries into mathematics to present mathematical practices as stakeholders of scientific activity. I then use this unconventional view on mathematics to define formulating as the activity of translating entities until they acquire the same form as previously-defined mathematical objects. In chapter 6, I build on these theoretical arguments to account for courses of action that successfully formulated some of the relationships among the data of a ground-truth database. This third and last case study will also make us appreciate some of the numerous links between ground-truthing, programming, and formulating activities, entangled processes that, sometimes, leads to the shaping of algorithms. These elements will finally allow me to touch on the topic of machine learning and artificial intelligence, here considered audacious yet costly attempts at automating formulating practices. In the conclusion, I develop some corollaries of the empirical and theoretical elements this inquiry unfolded.

Although ground-truthing, programming, and formulating activities follow each other in the present volume, they do not necessarily do so in the "real" life of action. In places such as the computer science laboratory we will soon get to know, these activities form a whirlwind process whose elements influence each other in a *dance of agency* (Pickering 1995). Moreover, even though this book's narrative thread is sequential—with subsequent chapters sometimes referring to previous ones—one may browse through it in different ways. Readers interested in ethnographic accounts may, for example, jump from one case study to another before eventually coming back to more theoretical pieces such as chapters 3 and 5. Readers who favor conceptual ventures may wish to go the other way round, starting with intellectual matters before coming back to down-to-earth accounts of practices. Of course, curious readers without specific expectations may also follow the book's thread, starting from chapter 1 and ending with the conclusion.

As mentioned earlier, it is important to keep in mind—almost like a mantra—that these three activities forming an empirical and partisan version of what algorithms shall be are not fixed nor exclusive. Even though they form, I believe, a refreshing and faithful conception of how algorithms come into existence, the precise ecology of algorithms would clearly benefit from further investigations. There are surely many more activities contributing to the formation of algorithms that future ethnographies and case studies will, hopefully, unfold. In that sense, although this volume does intend to bring about an alternative action-oriented constitution of algorithms, my arguments should also be considered preliminary propositions asking for further considerations.

At any rate, inscriptions make worlds only when read: at this point, my main concern is that readers—sociologists interested in the constitutive relationships of algorithms; computer scientists curious about an alternative action-oriented account of their work; or in fact, anyone concerned about the power, and beauty, of algorithms—are intrigued enough to come with me to explore some of the things that are happening in a computer science laboratory.

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The Constitution of Algorithms

Ground-Truthing, Programming, Formulating

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