4   The Transduction of Space

The modern city exists as a haze of software instructions. Nearly every urban practice is becoming mediated by code.

—Ash Amin and Nigel Thrift

Technicity and transduction account for how things *become* what they are rather than what they are.

—Adrian Mackenzie, our emphasis

In the opening chapter, we proposed that one of the primary reasons why software makes a difference to the world people inhabit is because *it modulates the conditions under which sociospatial processes operate*. We also suggested that software studies to date have largely ignored the role of space as a conceptual and analytical tool for understanding how and why software matters, instead prioritizing the role played by social relations and time. Space has been effectively relegated to the role of mere backdrop or inert stage.

In this chapter, we challenge such a view, arguing that space is a critical component, along with social relations and temporality, in understanding everyday life. Social relations do not operate independently of space or simply at a location, rather space is an *active* constitutive element in the production of social relations, communal formations, political organization, and personal regulation. In other words, the social is inherently temporal *and* spatial. Indeed, one only has to think of everyday living to realize how space provides a defining context in which relations unfold, and which in turn produce space. For example, people's labor is performed in particular workplaces, consumption unfolds in specific retail and leisure spaces, domestic life takes place within individual homes and distinctive neighborhoods, travel consists of journeys through and between localities, and communication is embedded within particular domains or links together geographically separated places. In all these cases, the spatial context is not incidental or inert, it is constitutive and productive—the *where* makes a difference to the *what* that unfolds. Space is a lively participant in the making

of meanings and memories. From this perspective, the work that software does is profoundly shaped by the co-constitutive relationships between software, social relations, space, and time; and in turn software matters because it alters the conditions through which society, space, and time are formed.

To commence the discussion we detail a brief genealogy of spatial thinking, summarizing how social scientists' understanding of the ontology of space has evolved. We do this in order to contextualize the recent development of an ontogenetic conception of space, and its utility in illustrating the productive relationship between society and space. In so doing, we make it clear how this new conceptualization differs from more traditional philosophies of space. Starting with implicit and absolute notions of space, we then outline relational conceptions of space, finishing with more recent ontogenetic understandings of space that argue for a shift in focus from questions concerned with "what is space?" to "how does space become?" (for a more detailed discussion, see Kitchin 2009). Developing the latter, we argue that code/spaces are best understood as ontogenetic in nature, bought into being through the technicity of software to invoke processes of transduction. Throughout the discussion we clearly privilege the spatial, but for good reason—to highlight how the social is thoroughly spatialized and to thus illustrate the relevance and potency of sociospatial approaches in understanding how and why software matters to everyday life; how it trasduces diverse spatialities.

A Genealogy of Space

Spatial thinking has developed apace in the last forty years, so much so that commentators now talk of a spatial turn within the social sciences. Prior to the 1950s, however, it is fair to say that beyond physics and theology, little conceptual work had been undertaken on the ontology of space. For social scientists, space was an *implicit* container or backdrop in which things happened. Even geographers—whose primary focus is the spatial—were more interested in describing the uniqueness of places and plotting spatial patterns across regions and within particular landscapes, rather than exploring the nature of space itself. Here, space was loosely understood in absolute terms, as having fixed dimensions across which objects of study could be measured and mapped. While not formally recognized as such by those working at the time, conceptually, space was natural, given, and essential, and spatial processes were teleological and predictable. Epistemologically empiricist, wherein facts spoke for themselves, research was largely analytically naïve, consisting of the accumulation of facts as evidence for generalist theories (Hartshorne 1959).

In the late 1950s and into the 1960s this implicit notion of space was rearticulated as an *absolute* ontology of space wherein space was understood as a geometric system of organization, "a kind of . . . grid, within which objects are located and events occur"

(Curry 1995, 5). Such a formulation, implicit previously, was now explicitly stated and was accompanied by an epistemology that saw geographical scholarship seek to reinvent itself as a "spatial science," transforming itself from an ideographic (fact gathering) to a nomothetic (law producing) discipline focused on locational arrangement, geographical patterns, and processes (see Schaefer 1953; Burton 1963; Harvey 1969). Here, space was defined and understood primarily through Euclidean geometry (with x, y, and z dimensions). The phenomena operating within a given space could be determined objectively and measured scientifically, then analyzed using spatial statistics and modeled quantitatively. Deeply essentialist in formulation, space is effectively reduced to the essence of locational geometry, its properties natural and given. For converts to this new way of researching the world, spatial thought became the science of spatial laws wherein observed geographic distributions and patterns could be explained through functional equations and modeled. Although few of these converts refer to the philosophy of positivism in their work, it is clear that many of spatial science's central tenets are drawn loosely from this school of thought (Kitchin 2009).

Developing from the 1970s onward, as a more explicit counter to the scientific ontology of absolute space, were calls for relational ontologies (see Crang and Thrift 2000). The concept of *relational* space was first articulated overtly within radical approaches within human geography (for example, Marxist and feminist geographies) that developed in opposition to the dominant methods and ideology underpinning spatial science. These theorists argued that spatial science was highly reductionist and by treating space as absolute in nature, phenomena were evacuated of social meaning and political purpose. Space, it was argued, was not a neutral and passive geometry, essentialist and teleological in nature. Instead, space was conceived as relational, contingent, and active, as something that is produced or constructed; "constituted through social relations and material social practices" (Massey 1994, 254). Space was not an absolute geometric container in which social and economic life took place; rather, it was constitutive of such relations.

In such relational thinking it was recognized that the spaces people inhabit—the built environment, transport systems, the countryside—do not simply exist, preformed and awaiting meaning. Instead, these landscapes, and the spatial relations they engender, are produced, they are made, shaped, managed, and given meaning by people; they are the products of diverse material and discursive practices that in turn actively shape social relations. Conceived of in these terms, an everyday space like a football stadium can be seen to be both a physical form constructed by certain agents and institutions for particular ends as well as a space given meaning through the daily labor of staff, the behavior and language of visitors, and the rituals and memories of fans: its use and occupation is shaped both by its material form and the immaterial meanings that coalesce around it (Hubbard et al. 2002). Epistemologically, what this relational conception of space meant was a significant shift from seeking spatial laws

to a focus on how space is produced and managed in contingent and relational ways by people to create certain sociospatial relations and not others.

In the last decade, a small cluster of scholars have begun to challenge absolute and relational conceptions of space, seeking to develop new understandings of space based on ontogenetic ideas. In so doing, they change the central question of inquiry from "what space is" to "*how space becomes*." Space (and everything else in the world), they argue, is not ontologically secure, it is not a fixable, definable, knowable, predetermined entity. Rather, space is always in the process of becoming; it is always in the process of taking place. Space, in these terms, is a practice, a doing, an event, a becoming—a material and social reality forever (re)created in the moment. At a fundamental level space achieves its form, function, and meaning through practice. Space *emerges* as a process of ontogenesis. As Doel (1999) has pointed out, from this perspective space can be understood as a verb rather than a noun, and he suggests that term space might better be replaced by "spacing" to better capture its perpetual production.

The ongoing practice of space can be illustrated in many ways. With respect to geographical form it is clear that the world is never static and fixed. Instead, the material landscape is constantly being altered, updated, demolished, and constructed through the interplay of complex sociospatial relations in ways that continuously moderate, in often subtle and banal ways, the spaces people inhabit. At a macroscale there are new local, regional, and national development schemes that are enacted daily to transform and regenerate built environments, transport infrastructures, and natural landscapes. For example, road layouts are modified, new buildings are designed, bus routes across the city are reorganized, new planning zones for industrial development are drawn up, land management schemes for drainage are devised, and so on, that adjust and revise the physical landscape and space-time relations of places. Locally, streets and buildings are always in a process of being refashioned and remodeled and spatial layouts rejigged. Roads are trenched for cabling, storefronts are updated, shop interiors are redesigned and maintained, trees are planted, grass is mowed, and litter is dropped and cleaned up. In other words, the material fabric and social relations of places are constantly created and recreated through spatial practices that vary in their pacing, so some changes are more immediately noticeable than others. As processes of erosion and entropy at abandoned buildings demonstrate, all places are in the course of change, slowly mutating from one state to another.

Similarly, the function of space is not static but alters with time (whether seasonally, as for tourist destinations, or daily, as for business venues and nighttime establishments) and the use of space is negotiated and contested between individuals and groups. Spaces have multiple functions and through the daily flux of interactions, transactions, and mobilities are always in the process of being made differently. For example, Trafalgar Square in London functions as somewhere to meet, to have lunch,

to chat, to visit museums, to gather for protests, to party, to take tourist photos, to travel across, to feed pigeons, to work on a food stall, to steal, to catch a bus or a subway train, to sunbathe, and to people watch. It is always in process, constantly being created in the moment as a collective manufacture composed of hundreds of recursive, interconnected relationships between people and place. Trafalgar Square does not simply exist, fully formed; a still landscape. It is endlessly remade, never the same, ceaselessly reterritorialized. As the Greek philosopher Heraclitus observed, "you cannot step twice into the same river, for fresh waters are ever flowing in upon you" (Russell 2004, 52).

Likewise, the meanings associated with spaces shift, ever changing with mood, action, memory, and events. Again in relation to Trafalgar Square, the meanings inscribed upon that location vary as a function of how the space is being used (as a tourist, or as a Londoner), how the viewer interprets Nelson's Column and the surrounding buildings (as visually stimulating scenery or an imperialist celebration), the social background and attitudes of a person, that person's memories and understandings of the Square, and so on. Similarly, meanings attached to home, workplace, particular buildings, and familiar journeys metamorphose with the passage of time. How space is related to, and the spatiality that engenders, can never be static, but emerges, varying over time, and across people and context.

The spatiality of Trafalgar Square (and indeed the notion of what Trafalgar Square is) is always in the process of taking place—its form, function and meaning is ever-shifting across people, time, and context. Its reproduction as Trafalgar Square *appears* to be relatively stable because it is maintained as such through a diverse set of discursive and material practices, including street cleaning, pavement repairs, policing, social norms, embodied conventions of behavior, history lessons, reading guide books, viewing postcards, sitting on steps, splashing in fountains, and many more. In other words, Trafalgar Square is constantly remade through consistently repeated, iterative practices enacted by people and things. These practices are citational in Butler's (1990) terms in that they endlessly, but imperfectly, cite the previous moment and thus give the appearance of coherence and continuity. Taken as a whole, it is important to realize these sets of practices are not planned or coordinated, nor necessarily conscious; they simply proceed. Moreover, many practices are easily forgotten or so ephemeral as to not be remembered, or are actively precluded and hidden to give impression of complete, fixed, and final existence. They are so banal that they are largely ignored, others are culturally invisible, and increasingly others happen automatically through the employment of technology. For example, this printed book consciously denies the evidence of the writing practices that brought it into being—the multiple versions, edits, revisions, and corrections made to sentences, sections, and chapters using word processors, pen and paper, and lengthy conversations. As such, Trafalgar Square is something that happens rather than something that is. Space

emerges, ceaselessly citing earlier spatial practices in a never ending, but always changing, cycle.

A number of spatial theorists have recently started to construct ontogenetic understandings of lived experience that seek to think through how space emerges in process, notably de Certeau, Rose, Doel, Thrift, and their respective collaborators. They have been joined by a growing number of others who have also extended such ideas to other core concepts underpinning spatial thought such as scale, place, nature, representation, and landscape, recasting each within an ontogenetic framework (challenging the ontological security of the concept itself, and rethinking each as emergent in nature).

De Certeau (1984) in *The Practice of Everyday Life* sought to move beyond theories centered on representation and observed behavior to consider the more subtle practices that are constitutive of both. In particular, de Certeau (drawing on Foucault) was interested in how people live within, negotiate, and subtly challenge circuits of power and the "proper" order of space as reproduced by dominant elites, such as states and corporations. For de Certeau (1984, 29), space is the outcome of the complex interplay between discursive and material strategies that seek to reproduce "places in conformity with abstract models" of scientific rationality and political economy, through persuasion, seduction, coercion, intimidation, and violence, and resistive tactics that seek to undermine such citational practices by "manipulat[ing] events in order to turn them into opportunities" (p. xix); such tactics could be overt like boycotts or organizing protests, or more covert such as transgressing social norms, ridiculing authority figures, lying on official forms, or ignoring the lawbreaking of others. De Certeau understood these tactics as performative, as often emerging unconsciously within context, so that as individuals "move about, their trajectories form unforeseeable sentences, partly unreadable paths across a space" (1984, xviii), where a trajectory "*comes into being*, the product of a process of deviation from rule governed . . . practices" (p. 5, original emphasis). Individuals actualize spatial possibilities, making space exist as well as emerge (p. 98); they invent and transform space. De Certeau (1984, 117, original emphasis) explains:

Space occurs as the effect produced by the operations that orient it, situate it, temporalize it, and make it function in a polyvalent unity of conflictual programs or contractual proximities. On this view, in relation to place, space is like the word when it is spoken, that is when it is caught in the ambiguity of an actualisation, transformed into a term dependent upon many conventions, situated as the act of a present (or of a time), and modified by the transformations caused by successive contexts. . . . In short, *space is a practiced place*. Thus the street geometrically defined by urban planning is transformed into space by walkers.

From a related perspective, Rose (1999, 248) draws on Butler's theory of performativity to argue that:

Space is a doing, that does not pre-exist its doing, and that its doing is the articulation of rela-
tional performances . . . space then is not an anterior actant to be filled or spanned or constructed
. . . [i]nstead, space is practised, a matrix of play, dynamic and iterative, its forms and shapes
produced through the citational performance of self-other relations.

For Rose, space itself, and thus its production, is brought into being through perfor-
mativity—through the unfolding actions of people. She argues that this produces a
"radically unstable notion of spatiality" that allows for a critical analysis of space as
"extraordinarily convoluted, multiply overlaid, paradoxical, pleated, folded, broken
and, perhaps, sometimes absent" (1999, 247). In other words, she suggests that a
performative understanding of space allows for a nuanced analysis that appreciates
individual differences across place, time, and context, and the paradoxical, contradic-
tory, and complex nature of sociospatial relations as lived and experienced by people.

Drawing on the ideas of Butler, Latour, and Deleuze, among others, Nigel Thrift
has developed the notion of nonrepresentational theory. Thrift suggests the world
emerges through spatial practices that are often unreflective and habitual, that are not
easily represented and captured because they are unconscious and instinctive; they
are performed without cognitive and rational thought (Thrift 2007). These human
practices are complemented by other actants—animals, objects, machines, circuits,
networks—that do diverse work in the world. In particular, Thrift is interested in how
new sentient technologies automatically produce space; that is, they bring space into
being without human interference. As such, he has examined the automatic produc-
tion of space by software embedded into everyday objects and environment enabled
devices (Thrift 2003, 2004a, 2004b; Thrift and French 2002).

While de Certeau, Rose, Doel, Thrift, and others have undoubtedly influenced our
thinking, in the rest of this chapter we detail our own take on the ontogenesis of
space. What we are particularly interested in, like Thrift and French (2002) and Crang
and Graham (2007), is the process by which software automatically produces space.
We theorize this process using the concepts of technicity and transduction, drawing
on the work of Mackenzie (2002, 2003) and Simondon (1989a, 1989b, 1992, 1995) to
argue that *space is constantly bought into being as an incomplete solution to an ongoing
relational problem.*

The Transduction of Code/Space

From an ontogenetic perspective, code/space, like all space, is beckoned into being
through various practices and processes. What makes code/space a unique spatial
formation, however, is that it is profoundly shaped by software. Code/space is quite
literally constituted through software-mediated practices, wherein code is essential to
the form, function, and meaning of space. Software acts as the catalyst to shift space

from an uncoded state to code/space, and works to maintain that transformation through an ongoing set of contigent and relational processes.

The reason why software can modulate the perpetual production of space is because it possesses significant degrees of technicity. This technicity is realized through the process of *transduction.* For Mackenzie (2003, 10, original emphasis), "transduction is a kind of operation, in which a particular domain undergoes a certain kind of onto-genetic modulation. Through this modulation *in-formation* or individuation occurs. That is, transduction involves a domain taking-on-form, sometimes repeatedly." Transduction is a process of ontogenesis, the making anew of a domain in reiterative and transformative individuations—it is the process by which things transfer from one state to another. According to Simondon (1992, 313), "the simplest image of the transductive process is furnished if one thinks of a crystal, beginning as a tiny seed, which grows and extends itself in all directions in its mother-water. Each layer of molecules that has already been constituted serves as the structuring basis for the layer that is being formed next, and the result is amplify-ing reticular structure."

Mackenzie (2003, 10) explains that "through transduction, a domain structures itself as a partial, always incomplete solution to a relational problem." From this per-spective, everyday life is seen as a stream of never-ending relational problems; for example, in writing, how to spell the next word, finish the sentence, structure the paragraph, and make a convincing argument. These problems are provisionally solved by some action consisting of individuations (looking in a dictionary, typing, editing, thinking, refining), thus transferring the situation from one state to another, yet also immediately creating a new problem to be solved (the next sentence). To take another prosaic example, a person traveling through a city constantly changes their relation to their milieu, thus posing a continuous supply of new problems, such as maintain-ing bearings, avoiding obstacles and other people, and reacting to situations such as the changing of traffic lights, the instructions of signs, requests for tickets, and so on, that have to be provisionally solved to make progress.

Individuations are the small incremental steps that constitute a transduction. They can consist of speech acts, physical movement, mental occurrences, memories, psy-chological perceptions, and physiological sensations, with the process of individuation resulting in a modulation in conditions of the person and their milieu. Most individu-ations are ordinary—routine, habitual, banal, beyond conscious thought, and reiterate previous individuations (walking by placing one foot in front of the other). In this sense, they are citational in that they imperfectly cite previous individuations, as with a layer of molecules in the growing crystal taking a similar form to the previous layer, or a step following a step. Others individuations are singular and can result in radical transformation (starting and stopping walking, changing direction, tripping).

Software solves relational problems by acting as a catalyst for transductions to occur and sustaining individuations within a modulation. Code thus transduces everyday

life, alternatively modulating sociospatial relations. From this perspective, *space is transduced*—bought into being—as a part of a provisional solution to an ongoing set of relational problems. Coded space and code/space occurs where the transduction of space is mediated by or is dependent on software. For example, using a checkout computer in a store to calculate the cost of goods and process a payment transduces its spatiality by modulating it into a state of code/space. Similarly, as we detail in chapters 7 through 9, software is increasingly providing the solution to relational problems, such as checking in for a flight (the space of an airport), cooking a dinner using a microwave (the space of the kitchen), playing a computer game (the space of a living room), and tracking goods from factory to shop (the spaces of logistics). In these cases, people's lives unfold in the moment as conjunctions between themselves, space, and coded objects (for example, bank cards), infrastructures (for example, cell phone networks), processes (for example, electronic fund transfer for direct debit payments), and assemblages (for example, the airport), in each case temporarily solving (or not) a relational problem by beckoning into being code/space. Thinking about how the transduction of space proceeds, and in particular the nature of code/space, raises a number of related issues. Here, we focus on four of them: the specter of determinism, the collectivized unfolding of space, the issue of scale, and the nature of structural power.

The Specter of Determinism

While the essential role of software in the transduction of code/space implies a certain technological determinism, the relationship is in fact contingent and relational. It is the case that the nature and meaning of space is dyadically produced through code, so that this mutual constitution makes a difference to the transduction of space, defining the practice and experience of that space. This is most obvious in spaces where code is used to regulate access and what is permissible and required behavior within those arenas (with associated penalties such as warnings, expulsion, fines, and imprisonment). Here, the mutual constitution of code and space is pervasive, consistent, routinized, effective (action is consistently instigated if the "rules" of code/space are violated) and determinate (but only in the sense that, as noted, failure of either code or space means that code/space fails and the intended transduction of space is not transduced).

Code does not determine in absolute, nonnegotiable means the transduction of space. Nor it is universal—that such determinations occur in all such spaces and at all times in a simple cause-and-effect manner. Rather, how code/space emerges, operates, and is experienced *is* open to rupture: code/space is embodied through the performances and interactions of the people within the space (between people, and between people and code). In this sense, code/space is not consistently produced, not always manufactured and experienced identically. Instead, code/space is constantly in a state

of becoming, produced through individual performance and social interactions that are mediated, consciously or unconsciously, in relation to the mutual constitution of code/space. As such, code/spaces should be understood and conceptualized as relational and emergent spaces in which software frames the unfolding but does not determine it. This can be illustrated in a number of ways.

First, the extent to which space and code are mutually constituted and their effects explicitly invasive—where code/space is visible and explicit in its consequences—alters as one passes through coded assemblages. For example, within transition zones in airports, characterized by the intersection of flow and security (check-in, security checkpoints, boarding, customs, immigration), the visible transduction of code/space is magnified, so that a highly particularized transduction of space is relatively consistently produced through the explicit scrutiny of *every* inhabitant (passenger or worker). In contrast, in the check-in area, or the departure lounge, or airport shopping mall, or the walkway from lounge to gate, or in the air, or baggage claim area, the mutual constitution of code and space is backgrounded and less invasive unless provoked. For the most part then, except for the small proportion of time spent in these transition zones, the vast bulk of time in code/space—either in the airport or in the air—is largely banal: spaces of chatting, waiting, shopping, fidgeting, reading, staring, and eating, (see Gottdiener 2001). The space may well be dependent on code to function as intended, but the work that software does fades into the background, allowing other social relations to dominate.

Second, even within the more overt and invasive code/spaces, spatiality is still a *negotiated* production. To continue with the air travel example, which is elaborated in detail in chapter 7, while the processing of passengers is verified and approved by code, the decision to allow onward passage through the assemblages is often mediated by an airport or airline employee (for example, the check-in agent, airline supervisor, security guard, flight attendant, or immigration official). These individuals are often vested with degrees of power to disregard and override the system, for example, allowing passage without full documentation or passage through security after setting off alarms. (Other times the staff can also choose to *not* override the software decisions and defaults for professional, commercial, or even personal reasons.)

Third, it is clear from observation that code/space is experienced differentially—not everyone experiences the work of software in the same way (and not simply on the basis of privilege). For example, while we would argue that an airplane is a code/space, it is experienced by crew and passengers very differently (as is every assemblage), but not in a binary way (all passengers and all crew have the same experience). Rather, code/spaces are *peopled* and despite the belief that airports and air travel are devoid of culture and meaning (so-called non-places, Augé 1995) the identity politics that sustain divisions in labor and between passengers still operate (factors such as age, class, gender, and race still shape social interactions) (Crang 2002). Code/spaces are

always diversely peopled and the meanings and experiences of code/spaces differ precisely because of how they are peopled.

Fourth, the relationship between code and people varies as a function of wider *context*. Mobilities, transactions, and interactions that involve code are historically, geographically, and institutionally embedded and do not arise from nowhere. Rather, code works within conventions, standards, representations, habits, routines, rules of thumb, and unofficial kludges, economic climates, and discursive formations, that position how code engages and is engaged with. The use of code is then always prefaced by, and *contingent* upon, this wider context.

Fifth, it is important to note that assemblages of code/spaces have accreted over time with technological advances and political and economic decisions to employ digital technologies. As such, they have not been planned in a comprehensive manner, but rather have *evolved*, often in an ad hoc manner and in response to specific needs. For example, new software versions and new technologies are always being sought to increase efficiencies and productivity, how different systems work together is constantly evolving, and the legal and economic frameworks underpinning code/space is negotiated and subject to periodic change (such as new licenses and changed pricing structures). The production of code/spaces is constantly evolving with these changes.

Finally, code/spaces are open to subversion. Here, the intended purpose of the code/space—productivity, security, safety, efficiency—is subverted through the system being duped. For example, people presenting false details to avoid being placed onto junk mailing lists, or stealing a person's identity for criminal gain. In this sense, while the system strives for perfection in terms of regulating and producing code/space, it continues to have cracks that allow unintentional sociospatial relations and formations.

The nature and transduction of code/space is then never fixed, shifting with place, time, and context (social, political, and economic relations and situations). Code/spaces are relational, emergent, and peopled.

Code/Space as a Collaborative Manufacture

Their swarming mass [people traversing a city] is an innumerable collection of singularities. Their intertwined paths give their shape to spaces. They weave places together. . . . They are not localized; it is rather that they spatialize.

—Michel de Certeau

The transduction of space is rarely, if ever, a singular occurrence. Instead, space and social life is beckoned into being through multiple, collectivized practices undertaken by many actants (including people, technologies, capta, nature, animals, and the weather) working in conjunction with each other and addressing multiple relational problems. Sociospatial relations are embedded in and emerge from a complex and

diverse matrix of social relations, with the interplay between actants shaping how space is beckoned into existence. To take a busy street as an example—it is full of actants (drivers, cars, traffic management systems, pedestrians, signs, workmen) that are all seeking to resolve particular relational problems (how to get from A to B; how to augment the driving experience for the driver and passengers; how to manage the road network to maximize throughput and safety; how to repair the road so that it meets certain criteria and standards). They do not seek to resolve these problems in isolation from each other. Rather they are solved relationally, taking account of shifting contexts and situations. For example, the drivers are moving their cars about in relation to other cars, traffic signals, and disciplining devices such as speed cameras; the multiple onboard systems are monitoring driver behavior and reaction and are shaping how the car is driven; and the traffic management system is monitoring road usage and reacting appropriately by changing the phasing of the lights.

Each of these actants has a degree of autonomy to do work in the world, but none can work in total isolation. The street emerges as a *collaborative manufacture* (Crang 1994, 686)—as a collective, heterogeneous series of transductions, the outcome of multiple complementary, competing, and sometimes contradictory, practices enacted by many actants. What this means is spaces emerge in a polyvalent manner, bought into being simultaneously by many actants, who do not contribute to the manufacture in the same way or in equal degree. They experience the resultant space from different perspectives and in diverse ways. Indeed, a pedestrian and a car driver both contribute to the spatiality of the road in varying ways and the road shapes their respective unfolding, sociospatial relations differently. Space is transduced as more than the sum of its parts.

Even when coded objects and infrastructures seem relatively localized, they can transduce spatiality in different ways. For example, a person talking loudly on a cell phone in a subway car reshapes its spatiality for other travelers, even if they only get to hear one side of the conversation. In this case, all travelers are modulated into the code/space of the cell phone user, although its effects are uneven and unequal, dissipating with distance from the phone or countered by other coded objects such as an MP3 player that blocks out the conversation (but which might also be affecting nearby passengers through noise pollution). Here, code is making a difference to the unfolding spatiality but in multifarious ways.

Scaling Code/Space

Once there was a time and place for everything; today, things are increasingly smeared across multiple sites and moments in complex and often indeterminate ways.
—William J. Mitchell

Just as there has been a rethinking of space, a similar reconceptualization has occurred with respect to the concept of scale. Initially, scale was implicitly taken for granted as

a "nested hierarchy of bounded spaces of differing size, such as the local, regional, national, and global" (Delaney and Leitner 1997, 93). Scale was treated simply as different levels of detail and modes of analysis. With the quantitative revolution in geographical analysis in the 1960s, scale took on more formal geometric properties, as an objective set of definable measurements useful for making relative comparisons. Recent research, however, has challenged scale as "unproblematic, pre-given and fixed hierarchy of bounded spaces," with theorists suggesting instead that scale be "conceptualized as socially constructed rather than ontologically pre-given, and that the geographic scales constructed are themselves implicated in the constitution of social, economic and political processes" (Delaney and Leitner 1997, 93; Jonas 1994; Marston 2000). In short, a number of authors have argued that scale is produced by actors and, therefore, open to transformation. Delaney and Leitner (1997, 95) posit that scale is (re)produced and transformed through the interplay of "context, actors, strategies, maneuvers, stakes, ideologies, and time." For some, such as Leitner (2004), this has meant rethinking scale as networks of relations which span space and cut across hierarchical structures (such as political units) that carve space up into discrete scalar units—in other words, scale works in complex ways both horizontally and vertically.

More recently, Marston, Jones, and Woodward (2005) have forwarded a proposition to eliminate the notion of scale, to be replaced with a flat ontology—one that neither privileges the vertical or horizontal (which tend to also create hierarchies of worth, such as cosmopolitan-parochial, or core-periphery). They understand scale as being epistemologically employed to put a shape on the world, but with no essential ontological foundation. Here, there is no natural scale, only scaling actions applied to the world to try to make sense of it, with this scaling emergent, constructed specifically for an analytic purpose. Consequently, Marston, Jones, and Woodward (2005) argue that spaces are not discretely bound (for example, the body, home, neighborhood, city, region), but are stretched out; the production of the intersections of diverse, spatially dispersed interactions and transactions that emerge through space and time (that is, an individual is simultaneously embedded in, works across, and is worked upon across space-time).

Likewise, we suggest that code/spaces (and indeed all space) are diversely, multiply, and ceaselessly scaled—they emerge as self-organizing systems of relations stretched out across space and time, the product of processes and relations occurring in many locales. For example, coded infrastructures create shifting, scaling networks linking together different actants located at distant sites or even on the move. An ATM may be physically located on Main Street, but it is connected in real time to a bank's server located several hundred miles away. At what scale is the transaction and withdrawal of money occurring? Or not occurring if the request is denied? Locally, nationally, both simultaneously, across a network? Similarly, consider the example of a busy road intersection. At what scale is the road being produced when drivers are using GPS

systems to navigate; traffic light phasing is being updated in real time by management systems that are physically located in another part of the city, that base their decisions on data collected from many different sensors dotted around the network; cars are being tracked by cameras that relay license plate details to information systems hundreds of miles away? We would argue that road intersection is being transduced through coded processes scaled across space-time.

Code/space then is *extensible*. It does not consist of solely of localized individuations. Instead, the transduction of space occurs through ongoing individuations across networks (assemblages of relations) of greater or shorter length, so that scales such as local and global become redundant. The ATM and the road intersection exhibit, to paraphrase Massey's (1994) phrase, a progressive sense of scale, the product of multiple networks working across time and space. And each network is just one of a multitude of networks, creating multiple, simultaneous but partial spatial-time configurations that are at once local and beyond.

Such configurations induce a constant, emergent mode of time-space distanciation (decisions and actions in one locale have an effect in another), although they do not necessarily mean that decisions or actions at one location produce material outcomes at another. For example, the use of an ATM leads to a communication with and updating of a banking captabase located somewhere else in the world, but does not necessarily change the material conditions there (one could be just checking an account balance as opposed to withdrawing money). This is not to deny that for each individual these networks, and the transduction of space they help induce, occur at the site at which they are physically located. Rather, it is to acknowledge that this localized transduction is the grounding of one part of a complex, geographically distributed network, and that this grounding might be just one of a number that are simultaneously happening across the network. Here, the network becomes "a mass of currents rather than a single line of force" (Whatmore and Thorne 1997, 291) and is a "performative ordering (always in the making) rather than a systematic or structural entity (always already constituted)" (p. 289).

Endogenous Structural Forces

It should be noted that our conceptualization of space as an ontogenetic, collaborative manufacture does not deny the salience of structural or institutional expressions of power, variously labeled and analyzed within frameworks such as political economy, corporate capitalism, neoliberalism, or theocratic power, or the processes, practices, or systems of institutionally situated and enacted structures, such as the state and its delegates. Clearly, there are significant institutional actors and systems in the world that do work through various means—they seek to manage and regulate social and economic life, supported by ideologies expressed through discursive regimes, in ways favorable to their interests and ongoing survival. However, an ontogenetic approach

recasts them not as monolithic, essential entities but as sets of ongoing, relational, contingent, discursive, and material practices, that are citational and transformative, and which coalesce and interact to produce a particular trajectory of interrelated processes. These practices emerge in context, inducing fresh transductions in collective life. As such, institutions and structural forces do not sit outside of collective life, shaping them from afar, but are (re)made through its performance, providing citational context at the same time that they are perpetuated. The means of production that underpin capitalist societies, and the ideologies that sustain and produce neoliberalism, are things that emerge in space-time through discursive and material practices, not things that are fully formed, preordained, and separate from the societies that they refer to and work upon.

In other words, for us, capitalist and neoliberal structures, and expressions of power, are things that emerge; ceaselessly produced through billions of actants every minute of every day. They appear to have form, substance, and solidity for two reasons. First, the actions performed by different actants generally appear to work toward a common goal (for example, the accumulation of capital) and are citational (they reproduce themselves in their own image, giving the appearance of stability). Second, they are supported by powerful discursive regimes that seek to make them clear and knowable to people; to make them appear commonsensical and rational (accepting economic and social injustice as inevitable and acceptable). Institutions, however, are complex, evolving entities consisting of amalgams of many people with different, competing ideas and interests, agendas, abilities, and ways of doing things, that emerge through processes of contestation and negotiation. Discursive regimes then are always in the process of taking shape, consisting of millions of exchanges, discussion, and documents, all read, interpreted, and acted upon in diverse ways. This is why the modes, of what appear to be coherent, knowable, consistent structural forces, when analyzed in any depth have no solidity; they are constantly in a state of metamorphosis. Indeed, they can never be fixed, as they are continuously in the process of being reproduced in millions of different ways. The work of institutions is then often haphazard, contradictory, and paradoxical.

While institutional forces and ideologies cannot be fixed, they are not without power, but this power is diffuse, contingent, and afforded, rather than held and wielded (see Allen 2004). However, the power is real nonetheless; for example, when expressed as violence with police ordered to raid a house and arrest an individual. The state draws its legitimacy and its power through the apparent solidity and actions of countless employees, and their associated discursive apparatus, that perform "the state" and by those who recognize the state through their interactions with state actors (even if their actions are ones of resistance) and thus afford the state, as a fluid, emergent entity, power. Here, power is conceived as something exercised by everyone and which is productive, complex, messy, and contradictory, bound up in everyday

practices of living, consisting of acts of domination countered by acts of resistance (Foucault 1977). Power thus unfolds through the enactment of strategies and tactics between people, rather than being wielded by one actor onto another. In the case of coded assemblages, several different institutions, each composed of many actors, seek to shape the transduction of space. These assemblages have no central control per se and possess a complexity much greater than the sum of the parts. In this sense, they are an assemblage that needs to be analyzed with respect to power, in Deleuze and Guatarri's (1987) terms, as striated—that is, complex, gridded, rule-intensive, regulated; and as complex systems with emergent properties (Holland 1998; Waldrop 1994). We discuss the issue of regulation and governance further in chapter 5 and also provide an illustrative example with respect to air travel in chapter 7.

Conclusion

In this chapter, we have provided a brief genealogy of philosophical of thinking about space, before setting out how our own work seeks to rethink the concept of space from an ontogenetic position. We have then elaborated this conceptualization, detailing how we understand space to be constantly in a state of nondeterministic becoming, operationalized through the process of transduction. Software makes a difference to everyday life, we argue, because it alternatively modulates the conditions through which space is beckoned into being, transducing code/space and coded space. Through their work in the world, coded objects, infrastructures, processes, and assemblages bring forth new possibilities and augment, mediate, supplement, and regulate spatial formation. This transduction of space is contingent, relational, scaled, and context-dependent, emerging through the discursive and material practices of a collaborative manufacture that is diversely and ceaselessly scaled. In part III we illustrate our arguments through three extended empirical examples—traveling by air, making homes, and practicing consumption. We highlight the transduction of various kinds of code/spaces and coded spaces, and how software is transducing new forms of spatiality and sociospatial governance that is profoundly changing how we partially solve the relational problems we encounter in our everyday lives.