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The anthropology of an equation

Sieves, spam filters, agentive algorithms, and ontologies of transformation

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This article undertakes the anthropology of an equation that constitutes the essence of an algorithm that underlies a variety of computational technologies—most notably spam filters, but also data-mining tools, diagnostic tests, predictive parsers, risk assessment techniques, and Bayesian reasoning more generally. The article foregrounds the ways ontologies are both embodied in and transformed by such algorithms. And it shows the stakes such ontological transformations have for one particularly widespread and powerful metaphor and device—the sieve. In so doing, this inquiry shows some of the complex processes that must be considered if we are to understand some of the key relations linking semiosis and statistics. Reflexively, these processes perturb some core ontological assumptions in anthropology, science and technology studies, and critical theory.

Keywords: ontology, sieves, algorithms, spam, data mining, digital humanities, critical theory, science and technology studies

> *[Bayes' Equation] solved practical questions that were unanswerable by any other means: the defenders of Captain Dreyfus used it to demonstrate his innocence; insurance actuaries used it to set rates; Alan Turing used it to decode the German Enigma cipher and arguably save the Allies from losing the Second World War; the U.S. Navy used it to search for a missing H-bomb and to locate Soviet subs; RAND Corporation used it to assess the likelihood of a nuclear accident; and Harvard and Chicago researchers used it to verify the authorship of the Federalist Papers. In discovering its value for science, many supporters underwent a near-religious conversion yet had to conceal their use of Bayes' Rule and pretend they employed something else*
>
> —Sharon Bertsch McGrayne, "The theory that would not die"

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Ontological transformativity and Bayesian anthropology

A sieve might be provisionally defined as any device that separates desired materials from undesired materials. Examples include sluice boxes and censors, strainers and centrifuges. My intent is to show how the sieve, as both a physical device and an analytic concept, is of fundamental importance to anthropology, and critical theory more generally. In order to achieve this, I begin by presenting some of the conceptual and political stakes of sieves in a relatively playful way, and show the incredible importance of sieves to anthropological concerns such as apperception and meaning, order and work, cooptation and exploitation.

I then detail the inner working of spam filters, algorithmic devices that separate desirable messages from undesirable messages. I argue that such filters are a particularly important kind of sieve insofar as they readily exhibit key features of sieving devices in general, and algorithmic sieving in particular. More broadly, I describe the relation between ontology (assumptions that drive interpretations) and inference (interpretations that alter assumptions) as it plays out in the transformation of spam as a kind of message style. I focus on the unstable processes whereby identifying algorithms, identified styles, and evasive transformations are dynamically coupled over time. And I show the direct and disturbing connections between key topics in critical theory and science and technology studies, such as culture and performativity, natural history and historical ontology, identity and agency, enclosure and disclosure, trials and channels, mediators and intermediaries, Freud's dream work and Turing's Test.

I next walk readers through Bayes' Equation, a mathematical formulation that lies at the heart of not just spam filters, but a wide range of other powerful computational technologies.[1] I show the limits of mathematical formulations through the formulations themselves by foregrounding some of the aporia of sieves. Along the way, I theorize various kinds of ontological inertia, showing how certain assumptions are "deeper" and so more difficult to historically transform. Concomitantly, I highlight various kinds of algorithmic ineffability, and show how certain processes are more difficult to mathematically capture. More than anything, and in conjunction with the other sections, this inquiry tries to demonstrate how equations and algorithms can simultaneously be subject to and contribute to anthropological analysis.

In a narrow sense, then, this article describes some of the key presumptions, possibilities, and pitfalls of a paradigm that might be best called Bayesian Anthropology. Yet in a broad sense, while the key categories developed here are embodied in the anthropological objects in question (in particular, spam filters and Bayesian statistics), they have the potential to be usefully and critically applied to other domains (when radically tweaked). As will also be seen, the categories generated reflexively apply to this very generation. This article is precisely an attempt to develop and delimit (as well as decry and destroy) a particular ontology: a relatively portable set of assumptions regarding the recursive and reflexive, as well as fragile and fraught, entangling of indices, agents, kinds, individuals, and worlds. In other

1. It thus ends where, empirically speaking, it should begin. I hope I am allowed to invert the ordering if only because the empirical object is relatively technical and I want to bring along as many readers as possible.

words, this article is meant to be an instantiation of what it instigates, a display of what it describes.

The stakes of sieves

Sieves are often defined as mechanical devices that separate desired materials from undesired materials.[2] For example, devices like gold pans and sluice boxes are ways of separating more dense and desirable materials (such as gold) from less dense and desirable materials (such as sand, mud, sticks, and so forth). A strainer is a type of sieve that separates a solid (such as pasta) from a liquid (such as water). And combine harvesters not only reap and thresh, they also winnow (by removing chaff from grain). Somewhat abstractly, the Sieve of Eratosthenes is an algorithm for separating prime numbers from natural numbers. Perhaps more in line with the concerns of this audience, norms and laws may sieve (accepting certain behaviors and rejecting others), as may price and infrastructure. In this last framing, devices such as turnstiles and admission fees, gatekeepers and logic gates, and passport checks and prescriptive grammars are sieves as much as sluice boxes. Other important sieving devices include not only Maxwell's demon (sieving for fast versus slow molecules), but also Freud's superego (sieving for acceptable versus forbidden wishes).

As these examples should attest, sieving has as wide a reach in our cultural imaginary as it does in our material environment. We even have a relatively productive linguistic construction that turns on it: to s*eparate the X from the Y* (the men from the boys, the sheep from the goats, the wheat from the chaff). Indeed, the last example, which comes from Matthew 3.12, is quite telling: not only does John the Baptist tell us that Jesus will gather the wheat into the barn, but also that he will burn the chaff with unquenchable fire.

In other words, separating substances is not an end in itself, but a means for further ends. In particular, just as the desirable materials may now be collected, the undesirable materials may now be destroyed. Moreover, it is always useful to remember that what is chaff for someone (say, a person who cannot digest it), may be sustenance for another: for example, a cow who can eat it, the fire that requires it for fuel, or the people who need the fire for warmth, illumination, protection, or divination. That is, just as there is wiggle room as to what has or has not been put through a sieve (i.e., are we at the input end of a sieve, and so still "aggregated"; or are we at the output end of a sieve, and so already "disaggregated"), there is also wiggle room as to which of the two substances sieved is a bad or a good. In this way, both the outputs of a sieve (wheat versus chaff), and the input-output relation

2. While many entities and agents are usefully framed as sieves, an important question that often arises is this: What does the concept (or metaphor) of a sieve itself sieve? That is, what kinds of processes are, and are not, sieves? Kockelman (2011) takes up the important relation between sieving and serendipity on the one hand, and between selection and significance, on the other. It argues that all four concepts are necessary to understand the multitude of multiverses. That said, this article tries to push sieving as far into the other three domains as possible and to show the scales at which it is privileged. Equally useful would be to stress how the other domains push back and, at certain other scales, are themselves privileged. Kockelman (2013a), for example, privileges significance and selection.

per se (prewinnowing or postwinnowing), are subject to classic framings: following Mary Douglas (1966), what is dirt for me may be order (or *matter in place*) for you; and following Gregory Bateson (1972), what is noise for you may be signal (or *meaning in place*) for me.

Finally, it is always useful to remember light polarizers: while two polarizers, at right angles to each other, may stop all light from getting through, if you put a third polarizer in between them, itself 45 degrees out of skew in relation to the other two, some light gets through. Note, then, that in sieving for a feature, the substances sieved may be affected by the sieving and thereby come to take on features they did not originally have—in particular, features that allow such substances to slip through such sieves. Think, for example, of Sigmund Freud's ([1990] 1999) ideas concerning the dream-work. And, more generally, think of the possibility of recoding and rechanneling any message so as to slip past a censor (Kockelman 2010a). We will return to this point below.

For all of these reasons, then, it is tempting to introduce a word that points back to our Boasian heritage (1889): we apperceive through our sieves as much as we sieve through our apperception. We appersieve, if you will. Or, if you go back to Kant ([1781] 1965), who defined the ego as the transcendental unity of apperception (whatever that means), we are our sieves.

Indeed, crucially, sieves have to *take on* (and not just *take in*) features of the substances they sieve, if only as "inverses" of them. A hole in the ground, for example, constitutes a simple sieve: anything with a diameter less than the hole will fall through; anything with a diameter larger than the hole will stay on top. In this way, to sieve a substance, the sieve must often have an (elective) affinity with the substance to be sieved and, in particular, the qualities sieved for—in this case size. In some sense, all sieves are *inverses* or even *shadows* of the substances they sort. By necessity, they exhibit a radical kind of intimacy.

Another good example of sieving is natural selection, which is sometimes framed in terms of serendipity (to generate variation) and sieving (to separate more fit from less fit variants). Note, then, that sieves are often themselves happenstance, rather than intentional, devices: their outcomes are as likely to be accidental as designed. And thus while many sieves are artificed entities or tools built precisely for the sake of their sieving function, many are atelic—generating various degrees of order for no good reason at all. And, as natural selection should also make clear, while any particular sieve may grade coarsely, and only for a single feature, each of the sieved groups can be further sieved into groups, and so on indefinitely. In this way, even though any actual division may be incredibly gross and simplistic, the concatenation and ratcheting of such gross and simple divisions can give rise to distinctions of great subtlety and beauty—for example, all the life forms that surround us.[3] Finally, note that the ability to sieve can itself be sieved: one can sieve sieves on the basis of their ability to sieve. Such sieve-sieving sieves may range from something as simple as quality-control mechanisms imposed by manufactures of

3. Note, then, even though most binary devices of the stereotypic sort, as we will see below, are really complicated sieving devices, there is nothing inherently *binary* about sieves per se: many sieve in a more or less, or graded fashion; and many sieve into more than two types.

pasta strainers (e.g., which strainers passed the countertop-drop test and so may be sold) to algorithms that use natural selection-like processes to generate more efficient algorithms.

In one sense, then, a sieve may be understood as the simplest of interpreting agents. See Figure 1. Its input can be any sign—for example, strings of any length composed of characters from any alphabet (e.g., text); or indices of any complexity composed of qualia of any kind (e.g., experience); or substances of any type composed of properties of any sort (e.g., things). Its output can be one of two interpretations—yes or no, true or false, accept or reject. Such interpretations can be enminded in cognitive judgments (good/bad) as much as embodied in physical actions (open/close); and they may be generated by processes grounded in "understanding" as much as "force," or "culture" as much as "nature," or "people" as much as "things," or "mediators" as much as "intermediaries," or "thirdness" as much as "secondness."[4] Crucially, what the signs in question correlate with (qua features of some significant object) and why that correlation matters (qua interests of some selecting agent), can be as wide or varied as possible. In particular, these devices are arguably shifters (e.g., words like *here* and *there*, *this* and *that*, *I* and *you*), in an expanded sense: while one can often give a relatively context-free description of their input-output relation, or sign-interpretant pattern per se, their actual meaning (as a relation between the features or values of the object and the interests or evaluative standards of the agent), *if they have one at all*, can only be determined by reference to a larger context, and may thereby shift (or sift) accordingly.

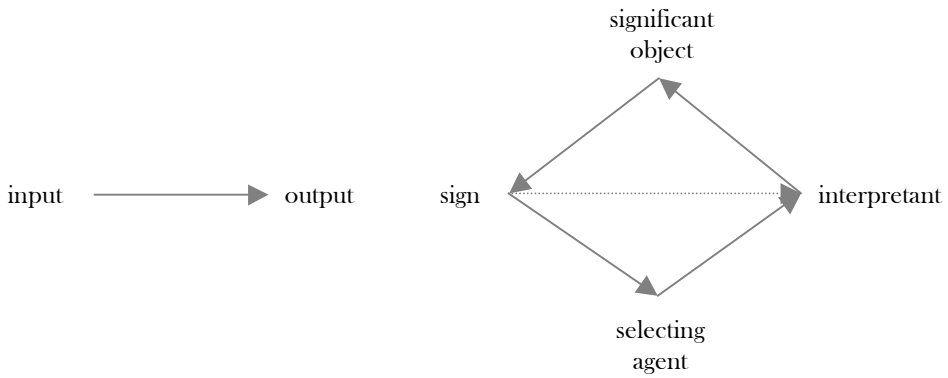


Figure 1: One-to-one mapping between input and output versus interpretant of sign in relation to interests of agent and features of object.

More generally, sieves are essential to information processing. In particular, deterministic finite automata, context-free grammars, and Turing machines (and hence a variety of more or less powerful "computers" in a theoretical sense) may be understood as devices that accept strings (qua sequences of symbols) as inputs and turn out one of two strings (accept/reject) as outputs (Sipser 2007). The set of

4. However you want to frame such distinctions and if you want to frame them at all.

strings they "accept" is sometimes called the language that they "recognize" (or, alternately, "generate" or "decide"). To get a sense of the power of such devices, which are in essence *text-generated and text-generating sieves*, note what can be represented by such sequences of symbols: all media, DNA, and the algorithms of the sieving machines themselves (i.e., the programs).

That said, a machine such as the combine harvester (mentioned above) should remind us that agricultural and industrial economies rely on sieves as much as information economies. Rather than thinking about *work* as the giving of form to substance for the sake of function, it may often be usefully understood as *the organization of complexity for the sake of predictability*. Take, for example, a gas in a container. We may do work on the gas by compressing it (applying a force through a distance and thereby decreasing the volume of the gas); and, in so doing, we obtain more information about the position of the molecules that make up the gas (in that they are now located in a much smaller volume than previously, and so we can point to their location with greater certainty). Or, loosely speaking, by exercising a power (i.e., moving a piston) we increase our knowledge (of where the gas is located in the container). In particular, what sieves really produce is patterns and hence predictability (perhaps no more and no less than poetry or peoples). And thus it is not so much that all work is done through sieves (though that may be the case, or certainly may be more and more the case) but rather that *all sieves do work*.

Except when they "don't work," an expression that is ambiguous in precisely the right way—for, as we will now see, the sieve, while in some sense the prototypic parasite (Serres [1980] 2007; Kockelman 2010a), is itself an unwitting host to a variety of parasites. For example, somewhat ironically, before you can sieve a substance you usually need to make sure the substance has already been sieved, such that it constitutes appropriate input in the first place. And thus, weapons of the weak fans, if you want to gum up the works of a sieve the best thing to do is to give it input that is neither here nor there: e.g., strings of symbols from an alphabet it does not recognize or indices unidentifiable in its ontology. The more singular your sign, in other words, the less likely it is that there is a sieve out there that has its qualities built into its design.[5]

For our second example, and as per the Hollywood image of a computer exploit, you can give a sieve input (say, particular strings, qua snippets of code) that commandeer its processor, or interpreting agent, for other ends. I'm not particularly interested in this type of parasite except insofar as it resonates with our above definition of a shifter in an expanded sense: that which has no object and serves no purpose and so can be coupled to any object and used for any purpose (depending on the context in which it is put—a context which includes the contents of its own input).

As a third example, and more technically, there is also the possibility that sieves of the Turing Machine sort (i.e., computers), cannot "decide" or "select," and hence cannot stop or "halt," but merely *cycle on infinitely* or at least *indefinitely*, unable to make a decision as to the status of a string: acceptable or unacceptable.

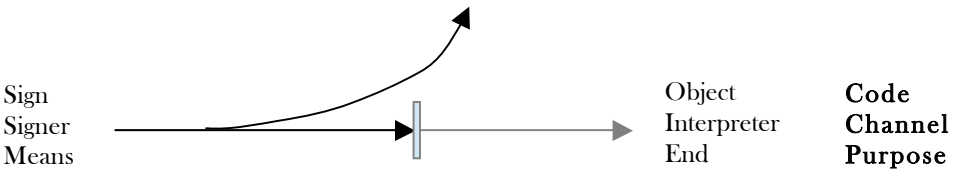
5. Recall our example of the hole and the strange intimacy sieves have in regard to the substances they sort.

To invoke the categories of Hannah Arendt (1958), your *actions* can ensure such a machine never *works* by making sure that it is always in *labor*.

As a fourth example, and somewhat more decisively, we can always just mix—which is, in some sense, the opposite of sieving: simply shake, aggregate, amass, spill, muddle, muddy, and more generally strategically discombobulate.

And finally, if sieves are machines that ensure that things are either *here* or *there*, we might just make sure that we only make things (and say things) that are neither here nor there.[6] This reminds us that *meaning*—ensuring that something is either here or there, in the sense that it makes or has sense—is the quintessential form of sorting. *His reply to my question was neither here nor there* (and so failed to sort the world for me). Or, as particularly pertinent to the history of anthropology, questions like: *is this permitted, may I eat at your table, can we marry each other, is he a witch, am I predestined?* In other words, given that we are all, in part, just sieves ourselves, we might all just stop making sense (if only in the sense of trying to make sense of it all).

See Figure 2, which owes as much to Claude Shannon's understanding of enemies and noise, as it does to Michel Serres' account of parasites, as it does to Charles Peirce's theory of thirdness.[7]



An object (action or sign) considered as a means to an end (or infrastructure considered as a path to a destination) is a second (or intermediary), but insofar as it implies (embodies or indexes) other ends it might be diverted to serve, or indeed implies any way it may fail to serve an end (whether original or diverted), it is a third (or mediator). The parasite is whatever inhabits such implications. That is, parasites reside in as much as off such systems, where their residence perturbs systems, pushing them off of old paths, and sometimes even pulling them onto new paths.

Indeed, the possibility of going awry, or at least of being judged so, is arguably the essence of such processes. Focusing on codes or representations, there is unconsciousness (being unable to represent some particular object) and misrepresentation (representing something incorrectly or in a highly refracted fashion). Focusing on channels or conditioning, there is repression (stopping a cause from having its effect) and rechanneling (creating conditions for causes to have unusual or unintended effects).

Figure 2: Parasite defined and exemplified in terms of code, channel, and purpose.

6. Notice, then, how sieves are inherently temporal (prewinnowing and postwinnowing, or aggregated and disaggregated) and spatial (here and there, or accept and reject). In some sense, they constitute a potential indexical ground, or point of departure, relative to which both a past and future and a near and far may be established.

7. It may also scale to include parasites of an economic kind (those who take value from a system without giving) and parasites of a biological kind (those organisms that benefit at the expense of other organisms).

In short, if we think of an entity's parasites as whatever implies other ends the entity could be used to serve (besides its intended purpose or function per se), or implies any way the entity might fail to serve its end (be it original or derived), these are some of the parasites of sieves—*parasieves*, in fact. Of course, if many sieves are not designed and thus cannot fail to achieve an end nor be diverted from an end (for they have no end), then they are in essence parasiteless creatures, and thus unexploitable entities—the lucky little devils.

The ontology of spam

By "spam" I mean unsolicited, commercial, bulk email; and the like.[8] And by "spam-filter," I mean a particular kind of sieve, one that uses mathematical algorithms to identify particular email messages as spam (or conversely, as "ham," in the sense of desirable as opposed to undesirable email) as a function of the kinds of features (letters, words, headers, etc.) such messages incorporate. As will be discussed, such algorithms usually assume (in a manner that may be easily updated) that general features of spam and ham messages are already known (qua typical kinds of incorporated features) and base their identification on such statistical assumptions. When they identify a message as spam, or likely to be spam (above a certain specifiable threshold of certainty), they can push it into a special folder, often outside the user's view. And, as a function of how often a particular filter creates false positives (incorrectly identifying ham as spam) or false negatives (incorrectly identifying spam as ham), the statistical assumptions themselves can be updated. Indeed, in cases like intentional deception (e.g., when senders of spam start packing their messages with signs designed to dupe spam filters), not only may statistical assumptions need to be updated but the relevant features to look for may have to be redefined, and the actual algorithms used for filtering may have to be redeveloped.

In what follows, after taking some time to make these topics more obviously relevant to anthropological concerns, we delve into these processes in much more detail and with much more generality. Readers will detect a Peircean orientation in what follows, but it is the definitions of these terms that matter, not the labels.[9]

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8. Spam has been usefully defined by Graham (2004) as "unsolicited mass email, usually advertising" (249). And this usage of the word (as opposed to referring to a particular brand of tinned ham) is usually traced back to an episode of Monty Python in which Vikings interfere with a conversation by chanting "spam" over and over again (Graham 2004). For a careful history and reflection on origins of the word and its importance to Internet culture, as well as its contrastive relation to the notion of community more generally, see recent work by Brunton (2010, 2012). And for more work by computer scientists on spam from a Bayesian approach see the original essay by Graham, as well as related essays at www.paulgraham.com/antispam.html. While not all spam filters use Bayesian filtering, or at least not only Baysean filtering (see, for example, www.spam assassin.apache.org), it is the general logic of the approach that interests me.

9. There are other terms that could have been chosen. For example, instead of the term ontology we might have used a word like culture, ideology, imaginary, ground, or theory. Instead of the word index, we might have used a word like sign (icon, symbol, etc.), evidence, qualia, inscription, experience, text, or token. Such an index might be constituted by a single word, a speech act, or an entire interaction; the smell of a rose,

The term *index* will be used to refer to any quality, or ensemble of qualities, that is potentially perceivable (to some agent). The term *kind* will be used to refer to any projected propensity to exhibit particular indices. The term *agent* will be used to refer to any entity that can perceive such an index and thereby project such a kind. The term *individual* will be used to refer to any entity that can evince indices to an agent and thereby be a site to project kindedness by that agent. And the term *ontology* will be used to refer to an agent's assumptions as to the indices, kinds, and individuals that constitute a particular world. See Table 1. Note, then, that material substances (gold, water, snow, etc.) are kinds, as are social statuses (speaker, banker, woman, etc.), as are mental states (believing X, fearing Y, etc.). In particular, we interpreting agents can project such kinds onto particular individuals (such as *this stuff*, *that woman*, *my dog*) as a function of the indices they express (the clothes they wear, the actions they undertake, the temperatures at which they freeze, the properties they possess, and so forth). *That's gold*, *she's a banker*, *he's afraid of the dark*. In this way, *ontologies drive interpretation*: by your index (sign), I infer your kind (object) and thereby come to expect (interpretant) other indices that would be in keeping with your kind (insofar as I have a particular ontology). Recall Figure 1.

We might exemplify such ontologies with a famous passage from *The adventures of Huckleberry Finn*. Dressed as a girl, Huckleberry Finn went into town to find out what people were saying about Jim. In this scene, Mrs. Judith Loftus has just "spotted him for a boy," and she is reporting to him the evidence she used to come to this conclusion.

> And don't go about women in that old calico. You do a girl tolerable poor, but you might fool men, maybe. Bless you, child, when you set out to thread a needle don't hold the thread still and fetch the needle up to it; hold the needle still and poke the thread at it; that's the way a woman most always does, but a man always does t'other way. And when you throw at a rat or anything, hitch yourself up a tiptoe and fetch your hand up over your head as awkward as you can, and miss your rat about six or seven foot. Throw stiff-armed from the shoulder, like there was a pivot there for it to turn on, like a girl; not from the wrist and elbow, with your arm out to one side, like a boy. And, mind you, when a girl tries to catch anything in her lap she throws her knees apart; she don't clap them together, the way you did when you catched the lump of lead. Why, I spotted you for a boy when you was threading the needle; and I contrived the other things just to make certain.

As may be seen, Mrs. Loftus has an ontology that she is here making relatively explicit. In particular, Huck is the individual in question. Mrs. Loftus is the agent.

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or the view from a balcony; something close by, or something far away; and so forth. Similarly, "individuals" are not necessarily, or even usually, individual people (in the sense of John, Sue, etc.), but can include: a swarm of bees, a swatch of flesh, the Colorado River, or the Pleistocene. And so on, and so forth. These terms were chosen because they seemed to be the least marked. In any case, the important issue is how they are defined; how each of their definitions is necessarily entangled with the others; and how each is frame- (agent-, or ontology-) specific, and so may both scale and shift accordingly.

Index	**Any quality, or ensemble of qualities, that is relatively perceivable (to some agent).** Spam example: *word-token ("sale," "sex," "enhance," "lose"), address of sender, type of attachment, etc.* General example: *actions, traits, properties, etc.*
Kind	**Any projected propensity to exhibit particular indices.** Spam example: *textual genre (spam versus nonspam)* General examples: *mental states, social statuses, material substances,* etc.
Agent	**Any entity that can perceive such an index and project such a kind (itself often an individual).** Spam example: *computer program (derivative), computer programmer (original)* General examples: *people, animals, instruments, etc.*
Individual	**Any entity that can evince indices (to an agent) and thereby be a site to project kindedness (by that agent).** Spam example: *some particular email message* General examples: *that woman, this stuff, my dog, your father, etc.*
Ontology	**The assumptions an agent has as to the indices, kinds, and individuals that constitute a particular world.** Spam example: *set of assumptions as to genres at issue and evidence available* General examples: *culture, worldview, imaginary, individual beliefs, taxonomy, etc.*

Table 1: The key constituents of ontology defined and exemplified.

The indices include particular actions (different styles of throwing and catching things, as well as threading needles, and techniques of the body more generally). And the kinds in questions are boy and girl—though they could have been any sociocultural identities under the sun (e.g., Huck's father could have gone into town trying to pass himself off as rich, sober, or sophisticated). Finally, note that Mark Twain, as the author of this scenario, has a relatively implicit ontology that includes within it assumptions about the ontologies of people like Mrs. Loftus. In particular, what kinds of beliefs does she have about particular kinds, like girl and boy? In this way, many ontologies are inherently metaontologies—one may have assumptions about others' assumptions (about one's assumptions about others' assumptions . . .), and so on, and so forth.

To give another example of the odd and pervasive nature of ontologies, we might turn to a meteorite—a kind of quintessential material substance, however otherworldly it might seem to be. While visiting a museum, I came across an exhibit that had several meteorites on display—which, to me, looked more or less like

rocks. Next to these meteorites was a placard telling the viewer how to identify a meteorite, offered as a list of potentially perceivable qualities: *should have smooth appearance*; *should be irregularly shaped, not round*; *should not be full of holes*; and so on and so forth, until it came to the last one, which gave the whole exhibit a decidedly Borgesian twist: *should not look odd*. In terms of the foregoing categories, the viewer of the meteorite is the agent, the meteorites themselves are individuals, each item in the list of potentially perceivable qualities could be an index, and the kinds in question are meteorite and rock (in the sense of a nonmeteorite, or more boring everyday sort of stone). But what is really special about this example, however quotidian and pervasive this kind of informative display actually is in our lives, is the way it highlights the reflexive, recursive, frame-dependent, and symbolically mediated nature of human ontologies (Lucy 1993; Agha 2007).

Note, first, that indices can themselves be reframed as kinds. In particular, the last index ("should not look odd") presumes that oddness is a sort of perceivable quality. But surely oddness can be understood in many different ways, such that there can be different indices of oddness. For example, odd for a rock is different from odd for a person; or odd in light of one interpretation (if this were a bar, his actions would not be weird) might not be odd in light of another interpretation (but we happen to be in church). In other words, what may be indices in one frame may be kinds in another, as well as indices of one kind rather than another. This is a very general point: not only may indices be reframed as kinds (and vice versa) but so too may individuals be reframed as agents, indices as individuals, ontologies as indices, and so on and so forth.[10] To offer one more example: meteorites themselves, when framed as kinded individuals, may be treated as indices of gravitational fields, God's wrath, and northern latitudes.

Second, while agents may often have seemingly "raw" indexical encounters with individuals, they also often have relatively "cooked" symbolically mediated encounters with individuals in which another set of signs (such as a list of perceivable qualities, or a placard bearing a name, or a display telling us where to look) does much of the interpretive work for us by telling us how to interpret and what to perceive (with more or less precision).[11] Phrased another way, even relatively immediate indexical encounters are usually symbolically and conceptually mediated—we are always only one or two steps away from the display case, tour guide, web page, literary work, parental point, expert opinion, prophetic pronouncement, sovereign assessment, or price tag. In this way, we interpretive agents are radically distributed: it is only me, in conjunction with the display case (itself the communicative trace of another set of actors), that allows me to interpret in this

10. That indices may be reframed as kinds (with their own indices) is, in part, dependent on the kinds of ontological transformations outlined below. In many circumstances, what determines one frame rather than another is the time-scale of interest, such that an agent's ability to type indices is relatively fixed, and so it is the judgment of kindedness (from these indices) that is relatively fluid. The fixed/fluid relation may turn on distinctions like hardware versus software or called versus calling function, and so forth.

11. In some sense, this is the generalized equivalent of the parent who not only points something out to a child but also describes what is being pointed at. And, of course, it is not without performative possibilities: *this is art*.

way. And framed yet another way, this example shows that many, if not most, of our ontological assumptions come from communicative practices with *others* (however objectified) instead of indexical encounters with *objects*.

Returning to our key theme, *styles are often best understood as kinds*. An interpreting agent examines an individual text (or artwork or artificed entity, more generally) and, as a function of the indices that make up the text (from the parchment it is written on, to the forms of parallelism it incorporates, to the language it was written in, to the actions of the characters, etc.), projects a certain kind onto it (Haiku, seventeenth-century Japan; Picasso, early blue period, etc.). And, as a function of this projection, such an agent comes to expect other indices from the text that would be in keeping with that kind: expectations as to its contents, authors, readers, contexts of presentation, likely endings, other features of its form, and so forth.

To return to our earlier concern, if style is a kind of kind, *spam is a kind of style*. In particular, and prefiguring many of the concerns of the following section, filters designed to stop spam from reaching your inbox embody an ontology as to the propensity for an individual spam message to evince particular indices (in contrast to a nonspam message). See Figure 3.

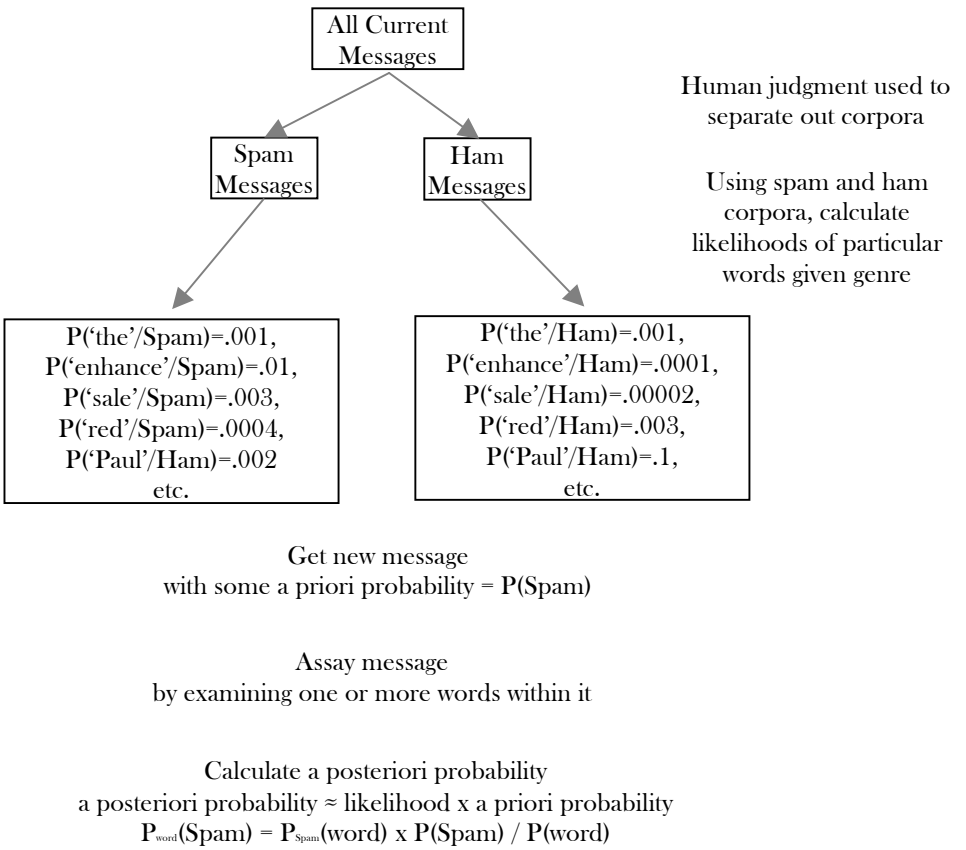

Figure 3: Some of the key steps in one approach to spam filtering.

Such propensities can be figured in many ways, but a widespread approach (Graham 2004) frames them in terms of likelihoods: in particular, the probability that a spam message contains a certain word (or quality more generally). Such likelihoods are usually found by doing frequency counts over particular words found in large corpora of known instances of spam (and nonspam) messages. Any new message is then assayed: one takes from it a number of words (or qualities) at random, gauges how likely these would be if the message was spam or not, and thereby updates one's certainty as to the spaminess of the message in question: say, from 50 percent uncertain (before the assays, qua a priori probability) to 96 percent certain (after the assays, qua a posteriori probability). In some sense, Mrs. Loftus was engaged in a similar kind of assay, or trial, however different the techniques she employed, via the little tests she "contrived just to make sure." And, similarly, the museum exhibit was, in some sense, a primer on extra-terrestrial rock assayal.

All that is fine and good: ontologies license an agent's interpretations as to an individual's kinds, be those kinds social statuses, material substances, or spam/nonspam messages, be that individual a person or thing, an artwork or text (or anything outside or in-between), and be that agent an interpreting human or an algorithmic machine. But rather than focus on how *ontologies license interpretations*, I am also interested in how *interpretations license ontologies*—and, in particular, I am interested in the coupling of these processes as it gives rise to the processuality of style. While there are many "natural histories" and "historical ontologies" (Silverstein and Urban 1996; Hacking 2002) waiting to be written of such interpretation-driven ontological transformations (in the full flush of their worldly unfoldings, as it were) it is worth theorizing some of their key dynamics.

Table 2 lists five kinds (!) of ontological transformativity—whereby an interpreting agent's ontology transforms via mediated encounters with an individual. The first kind of transformativity is simply performativity in a generalized sense: some index (icon, symbol, evidence, token, etc.) may change an individual's kind more or less irrespective of some particular agent's assumptions about it. Here go all the usual processes that produce kinded individuals in the first place, from chemical reactions that produce reactants to marriage ceremonies that produce husbands and wives, from performative utterances to contractual agreements, from socialization practices to evolutionary processes. Needless to say, the world is chock-full of kinded individuals (species, natural kinds, fundamental particles, personalities, social groupings, diseases, etc.), grounded in natural causes as much as social conventions, with various degrees of historical stability and geographic spread, and with various degrees of uptake and explicitness in the assumptions that constitute human and nonhuman ontologies. Needless to say, there are whole disciplines devoted to studying transformativity in this sense: physics, anthropology, chemistry, biology, and so forth.

The second kind of transformativity is perhaps the most quotidian, and often seems relatively deductive: indices may change an agent's ontological assumptions regarding the kinds that constitute a particular individual. For example, from your ring, I infer you are married; from its word frequency, I infer it is spam. This is where Mrs. Loftus aimed her inquiry.

1) Indices **(and signs more generally) may change an individual's kind irrespective of an agent's ontological assumptions.**

Examples: all processes in world (speech acts, chemical reactions, contracts, etc.) that produce individuals of particular kinds.

Ontological Inertia (in case of spam): occurs any time a message (spam or nonspam) is written and sent (whether by a person or a machine).

2) Indices **may change an agent's ontological assumptions regarding the kinds that constitute a particular individual**.

Examples: update certainty of individual's message type (spam or nonspam) in terms of words it contains.

Ontological Inertia (in case of spam): occurs each time a message is received.

Inferential Profile: often relatively deductive.

Mathematical Case: *a priori* probability becomes *a posteriori* probability, or change in P(Kind) to P_{Index}(Kind).

3) Indices **may change an agent's ontological assumptions regarding the indices that constitute a particular kind.**

Examples: likelihood of words in genre given corpus.

Ontological Inertia (in case of spam): occurs as statistical profile of corpus of assayed messages changes.

Inferential Profile: often relatively inductive.

Mathematical Case: change in likelihoods, or change in P_{Kind}(index).

4) Indices **may change an agent's ontological assumptions regarding the indices, individuals, kinds, and agents that constitute a particular world.**

Examples: update indices and kinds included in calculations.

Ontological Inertia (in case of spam): occurs as filter stops functioning correctly (e.g., too many false positives or false negatives).

Inferential Profile: often relatively abductive.

Mathematical Case: change in indices and kinds that are included in calculation or changes in individuals assayed and techniques of assaying.

5) Changes **in an agent's ontological assumptions about a world (in foregoing ways) may change the world about which the agent makes assumptions**.

Examples: looping effects (Hacking), internalization (Goffman, Mead), performativity (Austin, Arendt), etc.

Ontological Inertia (in case of spam): occurs as sending or receiving agents can internalize ontologies of receiving and sending agents (respectively).

Table 2: The key dimensions of transformativity defined and exemplified.

In some sense, the individual-kind relation (is it a dog or a wolf) transforms by reference to the individual-index relation (it bayed at the moon), while the kind-index relation stays constant (wolfs bay at the moon, but dogs do not).[12]

The third kind of transformativity often seems relatively inductive rather than deductive: indices may change an agent's ontological assumptions regarding the indices that constitute a particular kind. For example, from your behavior, I infer that married people do not fool around; from its word frequency, I infer that spam messages have different likelihoods than I thought. Had Mrs. Loftus, in her encounter with Huck, changed her assumptions about the throwing and catching abilities of boys and girls, this kind of transformativity would have been operative. In some sense, the kind-index relation transforms by reference to the individual-index relation, while the individual-kind relation stays constant.

The fourth kind of transformativity often seems relatively abductive: indices may change an agent's ontological assumptions regarding the indices, individuals, kinds, and agents that *constitute* a particular world (as well as regarding the possibilities of other worlds that could be constituted). For example, from your behavior, I hypothesize a new social status (say, the adulterer); from its word frequency, I hypothesize a new style (say, spam worth reading, or nonspam not worth reading). Had Mrs. Loftus hypothesized a new status—say, the transvestite (or something even more surprising to her in the sense of unconceptualized or unconventional)—this kind of transformativity would have been operative. In some sense, the types of individuals, indices, and kinds we take into account in our ontologies are themselves transformed.

Finally, there is a fifth kind of transformativity that may involve any of the other four kinds to various degrees: in particular, my assumptions about the world (as to its individuals, indices, and kinds) may transform the world about which I make assumptions.[13] In the case of spam, this dimension is essential: makers and senders of spam are often trying to second-guess the ontological assumptions of receivers and sievers of spam, and thereby pack their messages with indices that enable them to pass through such sieves. In other words, built into its ontology are assumptions about the other's assumptions about its own ontological assumptions. If Huck

12. This second kind of transformativity is often best understood in relation to text-level indexicality, where the indices in question are large-scale, emergent, fleeting interactional texts, where the kinds in question are social relations and personae of fraught and fluid natures, and where the interpretants of such kinds both generate and are generated by reflexive and often unconscious models of interaction (who are we, what is getting done though our coming together, to what end and why). If one dealing with those sorts of things, and the radically rich and open-ended interpretations possible, Goffman (1959), and similarly inspired scholarship (in particular, Agha [2007, and the many references therein]) is hard to beat.

13. A crucial note of caution: Such assumptions are as likely embodied and embedded as they are enminded and encoded. In this way, they too are a part of the world (and vice versa). For this reason, rather than talking about ontologies and worlds, it is best to talk about *worlded ontologies* and *ontologized worlds.* Kockelman (2013a) analyzes in detail the kinds of complexities that arise in dealing with such assumptions, treating them as modes of residing in worlds, as much as ways of representing worlds, and as radically distributed socially as well as emergent interactionally.

internalized part of Mrs. Loftus' ontology and so came to act more (or less) in line with her assumptions, or came to raise his own daughter or son to throw and catch differently, this kind of transformativity would be operative.

The first and last kinds of transformativity (1 and 5), in various guises, have received a huge amount of attention in anthropology, and critical theory more generally. In contrast, the middle three transformativities (2–4) are relatively undertheorized, and so will be the focus in what follows. In particular, these kinds of transformations not only have relatively different *inferential profiles* (e.g., deductive, inductive, abductive), they also have different *ontological inertias*.[14] For example, in the case of spam, transformativity #2 may occur as often as one receives a message and can assay its indices. Transformativity #3 may occur on a daily or weekly basis, depending on how fast one's corpus of messages grows and changes in statistical profile, such that one updates one's likelihoods as to the relative frequency of particular words in specific genres. Transformativity #4 might never occur at all, until one's spam filters stop working (often for reasons of transformativity #5); and so sievers of spam have to creatively rethink the indices they look for, the individuals that evince them, the kinds that they imagine, or the algorithms they use to sieve them. In this way, as we move from transformativity #2 to transformativity #4, ontological assumptions can be more and more resistant to change; and the kinds of assumptions that are transformed become *deeper* or more *immediate*. More generally, all ontologies embody a range of assumptions that, depending on the kinds of temporal scales in question, may be more or less fluid or fixed, if not unfathomable. Finally, not only do these transformations exhibit different ontological inertias, they may also get progressively more difficult to mathematically formulate and technologically automate, and so the transformations in question seem to turn more and more on human-based significance, and less and less on machine-based sieving.

Note, then, that sieves—such as spam filters—have desires built into them (insofar as they selectively permit certain things and prohibit others); and they have beliefs built into them (insofar as they exhibit ontological assumptions).[15] And not only do sieves have beliefs and desires built into them (and thus, in some sense, embody values that are relatively derivative of their makers and users); they may also be said to have emergent beliefs and desires (and thus embody their own relatively originary values, however unconscious they and their makers and users are of them). In particular, the values of the variables are usually steps ahead of the consciousness of the programmers (and certainly of users)—and thus constitute a kind of prosthetic unconsciousness with incredibly rich and wily temporal dynamics. Note, then, that when we make algorithms and then set those algorithms loose, there is often no way to know what's going to happen next (Bill Maurer, personal communication).

Finally, if one is not interested in spam versus nonspam per se, one may just substitute human versus nonhuman—for the core issues involved in the sieving of spam and the transformation of ontologies are identical to those underlying the

14. See Peirce ([1878] 1992, [1903] 1998) for more on these inferential profiles.

15. Indeed, reflexively speaking, one can watch their sieving activity (as indices) and infer their relatively derivative beliefs and desires (as kinds).

Turing Test (not to mention the diagnosis of maladies and the sexing of suspicious guests), and thus the sorting of souls, or the indexical styling of the human kind. But that said, most accounts of Turing's Test are quite a lot like Mrs. Loftus in that they never get past transformativity #2. But that is another story (Kockelman 2013b).

Mathematics of ontology and transformativity

I have described spam filters in terms of five dimensions of ontological transformativity. While the folks at McAfee, Barracuda, and SpamAssassin may not recognize themselves in the kind of language I have used, I have been at pains to render in qualitative terms, and with analytic precision, key aspects of the quantitative operations they design into their algorithms. Their training is in a storied branch of statistics derived from the work of Thomas Bayes (1701–1761), a Protestant minister and English mathematician who first formulated a special case of the theory that now bears his name. While his ideas have undergone a number of twists and turns since his death, Bayesian inference has found applications in fields ranging from machine learning to courtroom decisions, from medical diagnosis to linguistic reconstruction. More generally, and as intimated in the passage that opened this article, it is a key part of many techniques used for mining "big data"; it has played a key role in dozens of events of historical importance; it has a range of philosophical stances and counterstances associated with it; and weirdos and wizards of all kinds have been infatuated with it, or repulsed by it. As should be apparent by now, and as will be further elucidated in what follows, Bayes' most basic equation has something in common with that other quintessentially modern, radically portable, and infinitely transmutable form—the commodity. Strangely straddling materiality, mathematics, and metaphysics, the practices deploying it and the presumptions underlying it offer insights into conventional and cutting edge forms of value, as our coin example should now intimate.[16] (And, of course, it's not called "*mining* big data" for nothing.)

So having discussed the transformational dynamics of ontologies in relatively qualitative terms, we may now discuss the mathematical formulation of Bayesian inference and thus how it gets mediated by equations involving quantities of various qualities. To do this, let us turn to a scenario that goes back to Laplace ([1820] 1951), who was fourteen when Bayes' theorem was first published (in 1763, two years after Bayes' death), and who was the first mathematician to work with large data sets (McGrayne 2011:21).

Suppose that there are two kinds of urns in a room, each filled with a different assortment of coins, but otherwise identical in appearance. In the first kind of urn, 30 percent of the coins are copper and 70 percent are silver. In the second kind of urn, 80 percent of the coins are copper and 20 percent are silver. Suppose further

16. Readers of *HAU* should no doubt see the critical possibilities present in this scenario. For example, the relation to money, value, coins, storehouses, and tribute economies; the notion of containers and their contents, and ontologies grounded in visible/invisible, or appearance/essence, divides; what happens when urns and coins are replaced by beakers and chemicals (or any other kinds of entities from disparate ethnographic and analytic imaginaries); or when kinds and indices are ontologized in terms of persons rather than things, or strange interminglings; and so forth.

that the two kinds of urn are not equally distributed. Urns of the first kind are more prevalent, constituting about 66 percent of the urns in the room (so that urns of the second kind constitute the remaining 33 percent). You come across such an urn and would like to know which kind it is. So you reach in and pull out a coin—which happens to be copper. Given this evidence, what is the probability that the urn is of the first kind as opposed to the second (and thus is filled with one assortment of coins rather than another)?

To answer this question, and understand the logic behind the answer, it is useful to diagram the problem in a particular way. Figure 4a shows a square with a unit area equal to 1. This is the space of all possible outcomes (so that the probability of some outcome is 100 percent). Figure 4b shows this same area divided into two parts, one of unit area 2/3 (showing the percentage of urns that are of type 1), and the other of unit area 1/3 (showing that percentage of urns that are of type 2). These are your *a priori probabilities*: loosely speaking, the probability that the urn is of type 1 or type 2 *before* you pull out the copper coin. They are labeled P(U1) and P(U2), respectively. Note, then, that before you have even reached into the urn, just by way of how the problem was set up, you can say that the probability that the urn is of type 1 is about 66 percent.

Figure 4c shows each of these same areas further divided into two parts, representing the relative percentage of coins that are copper and silver in each of two kinds of urns. One part is of unit area 6/30 (= 2/3 x 3/10), showing the percentage of coins that are both in urn 1 and copper (and thus the intersection of all coins in urn 1 and all copper coins). Another part is of unit area 14/30 (= 2/3 x 7/10), showing the percentage of coins that are both in urn 1 and silver. Another part is of unit area 8/30 (= 1/3 x 8/10), showing the percentage of coins that are both in urn 2 and copper. And the last part is of unit area 2/30 (= 1/3 x 2/10), showing the percentage of coins that are both in urn 2 and silver. These are labeled P(U1&C), P(U1&S), P(U2&C), and P(U2&S), respectively. As may be seen, P(U1&C) is found by multiplying P(U1) by P_{U1}(C), and thus by multiplying the a priori probability that an urn is of type 1 by the *likelihood* that a coin in an urn of type 1 is copper (as per our initial formulation of the problem). That is, P(U1&C)=P(U1) x P_{U1}(C), and so forth for the other combinations.

Finally, given such a priori probabilities and such likelihoods, what you have been asked to calculate is an a posteriori probability: the probability that the urn is of type 1 (or type 2) *after* you pull out a coin of a certain metal (which itself constitutes a particular kind of evidence). This may be written as P_C(U1), and so on for other combinations. Figure 4d shows a geometric answer to this question: P_C(U1) is equal to 6/14, or the area P(U1&C) divided by the sum of the areas P(U1&C) and P(U2&C), which is equivalent to all the ways of getting a copper coin from an urn of type 1 (6/30) divided by all the ways of getting a copper coin regardless of the type of urn it is drawn from (6/30+8/30). In short, before you assayed the urn (by noting the metal of a coin pulled from it), the probability that it was of type 1 was about 66 percent. And after you assayed the urn, the probability was about 43 percent. Or, phrased another way, before the assay, you thought it was more likely to be an urn of type 1; and after the assay, you think it is more likely to be an urn of type 2.

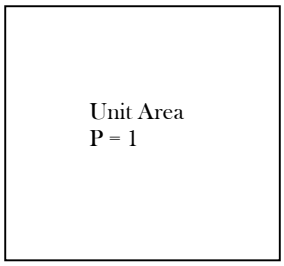

Figure 4a

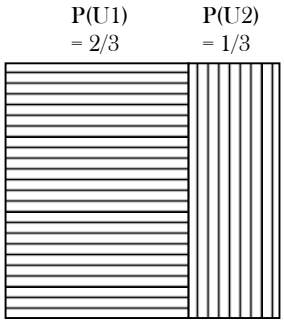

Figure 4b

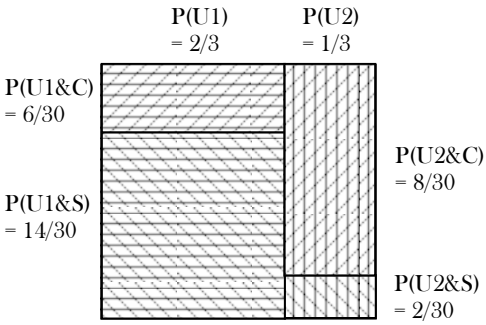

Figure 4c

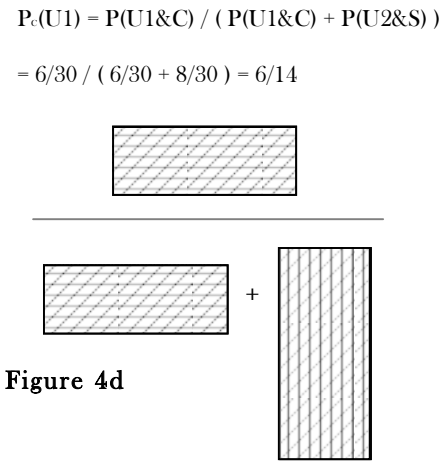

Figure 4d

Figure 5 is another way of showing the information available in Figure 4, foregrounding the algebra of the problem instead of the geometry, and so may be more familiar for some readers (though perhaps less intuitive).

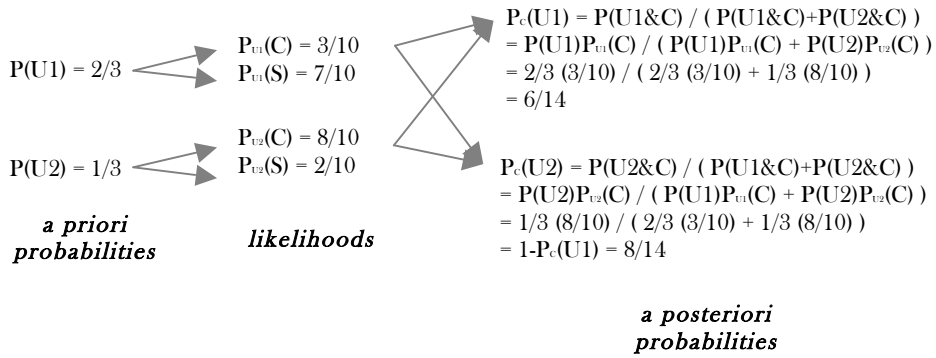

Figure 5: Relation between a priori probabilities, a posteriori probabilities, and likelihoods.

As may be seen, the key equation, after all is said and done, expresses the a posteriori probabilities in terms of the product of the likelihoods and the a priori probabilities:

$$1. \qquad P_C(U1) = \frac{P(C \,\&\, U1)}{P(C)} = \frac{P_{U1}(C) \times P(U1)}{P(C)} = \frac{P_{U1}(C) \times P(U1)}{P_{U1}(C) \times P(U1) + P_{U2}(C) \times P(U2)}$$

Such a way of formulating the problem (usually referred to as Bayes' Rule), however canned or trivial it may first appear, turns out to be incredibly general and powerful. In particular, to return to the concerns of the above section, replace types of urns with kinds; replace coins with indices; and replace particular urns (which may be of one kind or another) with individuals. In this way, we may think of Bayes' Rule as a heuristic that an agent might adopt for attributing kinds to individual via their indices, and thus a means for transforming its own ontological assumptions as to the kindedness of the individual in question. In this way, the core equation, in its full generality, may be expressed as follows:

$$2. \; P_{Index}(Kind) = \frac{P_{Kind}(index) * P(Kind)}{P_{Kind}(index) * P(Kind) + P_{-Kind}(index) * P(-Kind)} = \frac{P_{Kind}(Index) * P(Kind)}{P(Index)}$$

This equation may be interpreted as follows. On the left-hand side, we have $P_{Index}(Kind)$, or the probability that an individual is of a certain kind, in the context of its having evinced a particular index. On the right-hand side we have the product of a likelihood (that individuals of particular kinds exhibit indices of particular types, or $P_{Kind}(Index)$) and an a priori probability (or the probability, however subjective or tentative, that the individual was of that kind before it evinced the index, or P(Kind)). And this product is itself divided by the overall probability that the individual evinces the index regardless of its kind, or P(Index). Crucially, while we derived this equation in the context of a world that had only two sorts of kinds with two sorts of indices, it is completely general: one merely needs to sum over the product of likelihoods and a priori probabilities for each possible kind given the index in question.[17]

Equation 2 is not just simply a way of expressing Bayes' Rule in terms of our ontology, and thereby showing its relation to kinds as varied as mental states, social statuses, and material substances (as per our more general discussion above). It also shows us one way the three middle kinds of ontological transformativity may be understood in terms of one widespread mathematical formulation. (See the third column of Table 3, which compares such a mathematical formulation with logical and ontological formulations.)

17. To undertake such a sum, one has to be able to not just imagine a particular, and particularly bounded, totality. One often also needs access to an "avalanche of numbers," such that the likelihoods one uses to reckon are representative of some world—and thus statistical profiles that not only have particular truth values, but also often particular use values and exchange values, and so are radically caught up in knowledge, power, and profit. This is yet another way where radical forms of enclosure must be presumed, if only provisionally, in order to reckon in particular mathematical ways.

Traditional Inference	Ontological Transformativity	Bayes' Rule
Deduction *People die* (kind-index); *And Socrates is a person* (individual-kind); *Thus, Socrates will die* (individual-index).	**Transformativity #2** Indices change an agent's assumptions as to the kinds that constitute an individual.	**ΔP_{Index}(Kind)** (or a priori P goes to a posteriori P) Change strength of hypothesis (e.g., individual-kind relation) in light of evidence (e.g., individual-index relation).
Induction *Socrates (Aristotle, Plato, etc.) is a person* (individual-kind); *And Socrates (Aristotle, Plato, etc.) died* (individual-index); *Thus, people die* (kind-index).	**Transformativity #3** Indices change an agent's assumptions as to the indices that constitute a kind.	**ΔP_{Kind}(index)** Change likelihoods that are used to calculate changes in strength of hypotheses.
Abduction as Affirming the Consequence (early Peirce) *People die (kind-index);* *And Socrates died* (individual-index); *Thus, Socrates is a person* (individual-kind). **Abduction as Inference to Best Explanation (late Peirce)** Some surprising fact (F) is observed; If some hypothesis (H) were true, F would readily follow; Thus, there is reason to believe that H is true.	**Transformativity #4** Indices change an agent's assumptions as to the indices, kinds, or individuals that constitute a world (or at least to the possibility of other worlds that could be constituted).	**ΔKind, ΔIndex (also ΔIndividual, ΔAlgorithm, etc.)** Change types of hypotheses (or possible individual-kind relations) and types of evidence (or possible individual-index relations) that are used to calculate likelihoods.

Table 3: Comparison of traditional inference, ontological transformativity, and Bayes' Rule

In this framing, transformativity #2 is described by equation 2 itself, which expresses how a priori probabilities (and thus the strength of ontological assumptions) get changed into a posteriori probabilities, or the change in P_{Index}(Kind) before and after an assay of indexical evidence. For example, holding our assumptions about the indexical propensities of particular kinds constant (i.e., statistical profiles

of ham and spam messages), we use these propensities to infer the kindedness of an individual message as a function of the indices it exhibits.

Transformativity #3 is any quantitative transformation in likelihoods, or a change in P_{Kind}(Index) via changes in the statistical profiles of corpora. For example, holding our assumptions about the kindedness of a particular individual constant (this message is spam), we change our assumptions about the indexical propensity of particular kinds (say, spam messages are more likely to be personally addressed than originally assumed).

And transformativity #4 would correspond not only to changes in the types of indices assayed (e.g., perhaps words are not the best indexical types) as well as to changes in the types of kinds entertained (e.g., perhaps there are other genres besides spam and ham); but also to changes in the types of individuals assayed (e.g., perhaps spam is not limited to email) and changes in the types of sieving algorithms used in assays (e.g., perhaps Bayesian filters are not enough, insofar as they may easily be duped by spam senders who can internalize the ontologies of spam sievers, and react according, as per our earlier discussion of transformativity #5).

All this is another way of characterizing ontological inertia as introduced above, but now in mathematical terms: as we move from transformativity #2 to transformativity #4, we move from changes in relatively superficial to relatively deep assumptions. Phrased another way, changes at the level of transformativity #4 necessarily affect calculations at the level of transformativity #3 and #2 (but not vice versa); and changes at the level of transformativity #3 necessarily affect calculations at the level of transformativity #2 (but not vice versa). In this way, while the initial definitions of ontology and transformativity were extremely wide and meant to apply to relatively quotidian modes of semiosis, they also have relatively precise, mathematical analogs that apply not only to the case of sieving spam but also to any arena in which Bayesian inference is applicable—and thus to an incredibly wide range of processes. This is a key site where two of the foundational currents of anthropology—meaning and mathematics, or semiosis and statistics, and thus the early concerns of Boas and Durkheim, most transparently come together. Together with the theory of ontology and transformativity, it constitutes the basis of what I want to call *Bayesian Anthropology*, a potential paradigm that is probably as perilous as it is promising.[18]

18. Crucially, this linkage of Bayes' Rule and ontological transformativity also allows us to harness the generalizations underlying the mathematics itself—and thus the calculative possibilities offered via a range of mathematical affordances. Let me describe just two particularly relevant cases. First, equation 2 may be *iterated*, and thus applied again and again as more evidence is obtained. That is, with each new indexical encounter with an individual, one's previous a posteriori probabilities become one's current a priori probabilities, and so on, indefinitely. In particular, suppose that we want to calculate the probability that an individual is a particular kind (K), in the context of a bunch of evidence ($Index_1$, $Index_2$, $Index_3$, and so forth, up to $Index_n$). After some algebra, this can be expressed:

Conclusion

To conclude, it is worth extending a few claims, stressing a few caveats, and speculating on a few possibilities. First, the categories pertaining to ontology and transformativity, as summarized in Table 1 and Table 2, are potentially relatively general and thus widely applicable (Kockelman 2011, 2013a).[19] They should not be confused with the particular ways such categories are actually formalized (rendered or enclosed) in particular contexts—say, aesthetically (via narratives qua Huck Finn), instrumentally (via particular technologies like spam filters), logically (via formal modes of reasoning), and mathematically (via quantifiable qualities related through Bayes' equation). Or, inverting the frame (which follows the actual direction of empirical study), we may say that ontological transformativity, as it plays out in the highly specific context of sieving algorithms designed to stop spam, can be generalized (as an ideal type) and so usefully applied, with many caveats, to a range of other processes and practices.

In short, *do not confuse the enclosures with which we concluded (Bayesian inference) with the processes so enclosed (qua ontology-driven and driving interpretation)—the latter, in their actual unfolding, are often radically distributed and diverse, embedded and embodied, quotidian and quixotic*. Bayesian agents are a tiny subset of possible agents and so many other kinds of interpretative techniques exist.[20] One only need think, for example, of witch hunting among the Azande to realize that there are many other ways to justify a particular inference or ground a particular interpretation.[21] That said, I have simultaneously tried to show that the

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$$P_{I1\&I2\&\ldots\&In}(K) = \frac{P_K(I1) \times P_K(I2) \times \ldots \times P_K(In)}{P_K(I1) \times P_K(I2) \times \ldots \times P_K(In) + P_{\sim K}(I1) \times P_{\sim K}(I2) \times \ldots \times P_{\sim K}(In)} = \frac{\prod_{i=1}^{j} P_K(Ii)}{\prod_{i=1}^{j} P_K(Ii) + \prod_{i=1}^{j} P_{\sim K}(Ii)}$$

Second, this equation has a crucial *instantiation* in the context of spam filters. In such a case, there are two kinds (spam, ham), and there are a huge number of possible indices (say, tokens of all word types). Suppose, then, that we want to calculate the probability that a particular message (qua individual) is spam (or ham) given that we have assayed it N times, each time finding a particular word token (Wi). In such a context, the last equation becomes:

$$P_{W1\&W2\&\ldots\&WN}(Spam) = \frac{\prod_{i=1}^{N} P_{Spam}(Wi)}{\prod_{i=1}^{N} P_{Spam}(Wi) + \prod_{i=1}^{N} P_{Ham}(Wi)}$$

19. Three particularly important examples of careful empirical work leading to broad conceptual frameworks in regard to the relation between language, culture, inference, and epistemology are Enfield (2009), Hutchins (1980), and Sidnell (2005). I do not focus here on the linguistic mediation of inference and ontology, as I have foregrounded this process in other work, when the kinds in question are "mental states" (Kockelman 2010b).

20. And, indeed, Bayes' equation *per se* only applies to transformativity #2.

21. Moreover, the four enclosures described here are just a small sliver of possible modes of objectification. There are other styles of reasoning underlying inference, other forms

issues that come to light in this small subset of the possibility space (e.g., the categories developed in Table 1 and Table 2, and various properties of sieves and practices of sieving) are quite general and incredibly important.

Framed another way, and such caveats aside, I have tried to introduce ten categories (themselves kinds, and so reflexively part of their own system of categorization) through which one may explore, interpret, know, provoke, create, and incite worlds. Such categories are not only meant to be minimalistic, they are also meant to be portable: their meaningfulness and means-ends-fullness should be applicable to many contents and applicable in many contexts.

Second, it should be noted that the relation between kinds and indices is legion in social theory. They map, respectively onto categories like status and role (Linton), langue and parole (Saussure), competence and performance (Chomsky), power and its exercise (Hobbes), and even essence and appearance (as understood in certain philosophical traditions). Thus, from the standpoint of this article, categories like langue and parole are really ontology-specific (and often discipline-specific) renderings of more general categories. As should be stressed, such discipline-specific categories are by themselves not particularly useful. Rather, they need to be articulated in relation to a broader set of categories (minimally: ontologies, individuals, and agents), and resolutely theorized in terms of their mutual transformations (minimally: the five kinds offered here). That said, such frameworks, however inadequate, are quite powerful in certain ways; and so I thought it was worth noting such connections so that potential conceptual bridges can be dismantled as much as maintained.

Third, and as an example of such conceptual bridging, note that there are two incredibly important ways such categories may be framed in terms of economic processes. From the standpoint of microeconomics, the relation between indices and kinds maps onto the relation between preference relations and utility functions. In particular, one may examine the preferences of an actor (e.g., which commodities did they choose over others in particular situations), infer their utility function (a kind of topological grading of their generalized desire), and come to expect other preferences that would be in keeping with that function. Needless to say, there are great efforts underway to infer various *kinds of consumers*, themselves densely figured in terms of all the other kinds any individual might also belong to (social categories, political beliefs, physical characteristics, etc.), in order to both tap and govern, or exploit and coerce, their utility functions. Data mining, consumer targeting, and political governing are fast becoming indistinguishable—and the algorithmic processes described in this article are one particularly important way such processes are carried out.

From the standpoint of critical political economy, the relation between kinds and indices maps onto the relation between labor-power and its exercise. While this move has roots in Hobbes, much of the incredible power of Marx's critique of capital comes from his assumption that the difference between labor-power (or what the capitalist purchases by paying a wage) and its exercise (or what the capital-

of mathematics underlying machine learning, other kinds of sieves besides spam filters, and of course other aesthetic sensibilities as to how to suss out the true nature of a suspicious guest (as well as recount and imagine such sussings).

ist recoups when he sells the products of that power) is not only the center of veiled inequality within the system (as envisioned by him, with the ontology he had, at the time he was working), but is also at the center of the semiotic mediation that generates (and is generated by) the systematic misrecognition of the origins of value. This, in its generalized form, and not so much the difference between concrete and abstract labor, may be the real pivot of political economy. In short, one could rethink ontologies and their transformations (as laid out above) from the standpoint of critical political economy (to wit, what more radical modes of mediation link indices to kinds), just as one could rethink critical political economy from the standpoint of ontologies and their transformations. But that too is another story.[22]

Finally, we may return to the original subtitle of this article ("Hunting ham and sieving spam") and take up the venatic origins of meaning. The historian Carlo Ginzburg (1989) entertained the idea that our propensity to read signs had its origins in the necessity of tracking animals. Or, in terms of the foregoing categories: our ancestors (qua agents) were sieved on the basis of their ability to correctly infer animals (qua kinds) from their tracks (qua indices). That is, insofar as one is good at judging from an animal's tracks where it is going, how badly it is wounded, how big it is, and what kind of animal it might be, one is better at securing food (and ensuring that one doesn't become food).

Potentially just a just-so-story, to be sure. My interest is that, in this same essay, Ginzburg described the work of the art historian Morelli, who came up with a new technique for linking unattributed art works to old masters: instead of looking at key motifs as evidence of authorship (an important index-kind relation), he started focusing on minor details, like the shapes of ears, which he thought were more likely to be unconsciously drawn, and so not subject to strategic manipulation. In terms of the foregoing categories, Morelli was engaged in ontological transformativity of the fourth kind. He altered the very evidence scholarly agents look for in

22. From one vantage, Marx ([1867] 1967) may be understood as having undertaken the anthropology of an equation—in particular, the cycle of production: M-C (=MP+LP)...P...C'-M' (=M+s). The capitalist takes a certain amount of money (M) and uses this to buy a commodity (C), which consists of two parts: on the one hand, there are means of production (MP), what is worked on and what is worked with; and on the other hand, there is labor-power (LP), which consists of people with the mental and physical capacity to work. When this labor-power is put to work utilizing these means of production, the production process (P) results in another commodity (C'), which the capitalist then sells for a certain amount of money (M'). In this way, the original sum of money (M) divides into two parts: a portion (c), called "constant capital," is used to purchase the means of production; and a portion (v), called "variable capital," is used to purchase the labor-power. And, assuming all goes well for the capitalist, the final amount of money (M') is equal to the original sum of money advanced (M=c+v) plus a surplus (s). If the first parts of *Capital* set up this equation and describe the interactions among its key variables (M, C, s, LP, etc.), parts VIII and VII of *Capital* may be understood as boundary conditions and limits. For example, what did the system look like at time t equals zero (think primitive accumulation)? And what will the system look like as time t goes to infinity (think of changes in the value composition of capital [v/c and v+c] under regimes of extended reproduction), when the outputs of one cycle of production become the inputs of a new cycle.

their attempts to infer authorship and thereby inaugurated a minor revolution in art history.

Crucially, for Ginzburg, Morelli was a precursor to Freud, who did something similar: moving attention from explicit speech and conscious thought as relatively transparent representations of ordinary beliefs and desires, to dreams and neurosis as evidence of unconscious and undesirable desires (a particularly important kind of projected propensity). He not only introduced a new kind of interpretive agent (the analyst) but his texts trained generations of such agents to do such analysis (his clinical writing being, in some sense, akin to the meteorite display). Finally, we might add Erving Goffman to this list: he introduced the interactional order, constituted by a hurly-burly of highly contextually contingent, fleeting, and unconscious gestures; and he introduced a new set of kinds (animators, authors, principles, ratified and unratified bystanders, etc.) that were revealed in and consequential to such interaction. In short, one reason scholars such as Freud and Goffman are so important is that they made relatively large interventions at the level of transformativity #4 (with enormous repercussions for the other modes of transformativity as well).[23]

Finally, and perhaps needless to say, ethnography in its most daring undertakings (and as formulated from its very beginnings) has always been about the uncomfortably transformative mediated immediacy of the encounter, an encounter designed—however often it is diverted from that end—to bring us one step closer to an other's ontologized world (or worlded ontology) and one step further from our own—be that other an interpreting human or a sieving machine, a parasite or a meteorite, Maxwell's demon or Bayes' equation.

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A shortened version of this article was presented at the annual meetings of the American Anthropological Association in 2011, and longer versions were presented in 2013 to the Anthropology Departments at the University of Pennsylvania, Yale University, the CUNY Graduate Center, Brown University, Bard College, and the University of Texas at Austin. In these forums, and in a few other key places, I received particularly transformative comments, criticisms, and

23. Note, then, that ontologies are held by actors and analysts alike. Weber's *Economy and society* (1978) is, in some sense, our largest compendium of sociological kinds. And his understanding of the functioning of ideal types in the *Methodology of the social sciences* (1949) was, in some sense, a kind of scholarly strategy (and editorial ethos) to help we interpretive agents ferret out indices of bad ontologies (qua sociological imaginary), push moments of scholarship to their crisis, and thereby transform our ontologies of analytic categories. In other words, there is a particularly important kind of kind that should be mentioned: the bad (or good) ontology, in the sense that it is deemed less than adequate to the world it represents (often by reference to a "higher" ontology). With this kind of kind, there is a crucial kind of index: any sign that indicates our ontology is at odds with a world or brings the lie of our ontologies to light. In this way, we may offer one possible framing of what is to be meant by *world*: whatever is potentially represented by, and resistant to, an ontology. It is thus an eerie commingling of firstness (possibility), secondness (resistance), and thirdness (representation).

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Anthropologie d'une équation. Tamis, filtres anti-spam, algorithmes agentifs et ontologies en transformation

Résumé : Cet article entreprend l'anthropologie d'une équation qui constitue l'essence d'un algorithme sous-tendant une variété de technologies : notamment les filtres anti-spam, mais aussi des outils d'exploration de données, tests de diagnostic, analyseurs de prévision, techniques d'évaluation des risques, et raisonnement bayésien plus généralement. L'article met en avant comment les ontologies sont à la fois incorporées et transformés par ces algorithmes. Il montre également les enjeux que ces transformations ontologiques ont pour une métaphore et un dispositif particulièrement répandu et puissant : le tamis. Ce faisant, cette enquête montre quelques-uns des processus complexes qui doivent être considérés si l'on veut comprendre certaines des relations clés qui relient sémiose et statistique. Par réflexivité, ces processus perturbent certaines hypothèses ontologiques fondamentales des études d'anthropologie, de science et technologie, et de théorie critique.

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