Cyber Metaphors and Cyber Goals: Lessons from "Flatland"

Pierre Trepagnier
Cyber Systems and Operations MIT Lincoln Laboratory Lexington, Massachusetts 02420,
ptrepagnier@ll.mit.edu

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Abstract

Reasoning about complex and abstract ideas is greatly influenced by the choice of metaphors through which they are represented. In this paper we consider the framing effect in military doctrine of considering cyberspace as a domain of action, parallel to the traditional domains of land, sea, air, and space. By means of the well-known Victorian science-fiction novella Flatland, we offer a critique of this dominant cyber metaphor. In Flatland, the problems of lower-dimensional beings comprehending additional dimensions are explored at some length. Inspired by Flatland, our suggested alternate metaphor for cyber is an additional (fourth) dimension. We then propose three common characteristics between the world of Spaceland as experienced by Flatland natives and that of Cyberland as experienced by humans, and finally explore some possible new insights suggested by the Flatland dimensional metaphor.

Introduction

"...the importance of metaphor is that it underlies all forms of understanding whatsoever, science and philosophy no less than poetry and art."

— Iain McGilchrist [1 p. 71]

The Problem

In United States Department of Defense (DoD) doctrine, Cyberspace is normally presented as a novel "domain" of action, *alongside* traditional warfighting domains. For instance, Joint Publication 3-12 states "Cyberspace, while a global domain within the information environment, is one of five interdependent domains, the others being the physical domains of air, land, maritime, and space [2]." This concept is often presented graphically in ways similar to Figure 1, taken from [3], and although it has been criticized (see, e.g. [4 p. 1]), it remains dominant within the DoD.
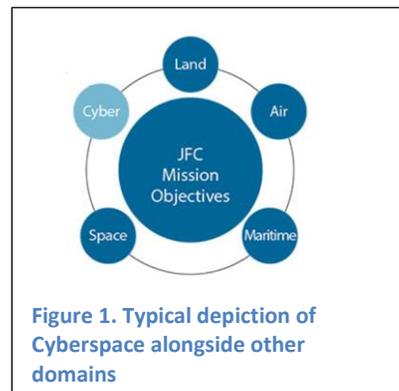

Figure 1. Typical depiction of Cyberspace alongside other domains

We claim, however, that this representation of cyberspace obscures significant differences between cyber and the four other spatial domains. Consider the issue of domain separation. If you are in the middle of Central Asia, or on the Moon, it will take you a long time to get to the maritime domain. From any of the traditional domains, however, one can slip into cyber essentially instantly. It makes more sense to think of cyber not as another domain like land and maritime, but as another dimension. Cyber is everywhere, alongside the x,y, and z dimensions; it is just that until recently we were confined to the cyber=0 hyperplane, and ignorant of this additional cyber dimension[*].

Dimension vs. domain is by no means a distinction without a difference. The DoD is a key player in the realm of cyber. In addition to spending roughly $5.5 billion per year on cyber operations [5], DoD also shoulders the majority of responsibility for the US Government's defensive cyber operations, and essentially all of it for offensive cyber operations. DoD doctrine in the realm of cyber is therefore critical in shaping both policy and perception in this area. Our thesis is that the principal metaphor chosen to express DoD doctrine is misleading in important respects and causes incorrect framing effects, which in turn lead to incorrect actions and policy.

It is well-established that the choice of metaphor influences how we reason about complex subjects [6], and that metaphorical language pervades thinking about the abstract [7]. Metaphors shape our perceptions and actions without our noticing. For instance, it makes a difference if crime is conceptualized as a "beast" or a "virus." "Participants who read that crime was a beast were more likely to propose fighting back against the crime problem by hiring police officers and building jails – to catch and cage the criminals – than participants who read that crime was a virus." [6 p. 5] Unfortunately, we do not have the

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[*] In some sense cyber is closer to air; military operations were approximately confined to a 2D surface embedded in 3D space from the beginning of recorded history to World War I. Military doctrine evolved both rapidly and dramatically after air warfare was introduced, as for instance, the aircraft carrier replaced the battleship.

space here to recapitulate the conclusions of [7] and [6] in any detail, but wish to emphasize that we both think with and live by metaphors; these results inform the entire approach of this essay. In the remainder of it, we will consider how a different metaphor — explicitly reasoning about cyberspace as an additional dimension, rather than just another warfighting domain implicitly similar to the others, might affect our approaches and actions in reasoning about it. We will do so by looking for parallels in the pioneering satirical science fiction novella Flatland[†], first published in 1884 and written by Edwin Abbott Abbott. Flatland treats in some detail the comprehension of a three-dimensional world by intrinsically two-dimensional creatures, who are confined to the z=0 plane. We argue it sheds light on our related metaphorical problem of the comprehension of a fourth cyber dimension by intrinsically three-dimensional creatures who live in the cyber=0 hyperplane.

Flatland

Flatland the novella is divided into two parts, Part I: This World, and Part II, Other Worlds. In Part I, Abbott, in the guise of his narrator A Square, works out in some detail how a two-dimensional world would actually "work," including things like houses and (notably) perception. However, for the purpose of exploring dimensionality as a framing metaphor, Part I is relatively uninteresting, and we shall pass on to Part II, in which lower-dimensional perception of higher-dimensional space gets investigated in detail.[‡]

Part II is principally concerned with the visit to Flatland of the Sphere from Spaceland in the wee hours of New Year's Day, 2000[§]. The Sphere appears to Square and other Flatland inhabitants as a circle which can magically change size, or vanish altogether, depending on where the Sphere intersects Flatland's z=0 plane (Figure 2). It turns out that once every millennium an emissary from Spaceland comes to Flatland to proclaim that there is a land of Three Dimensions.
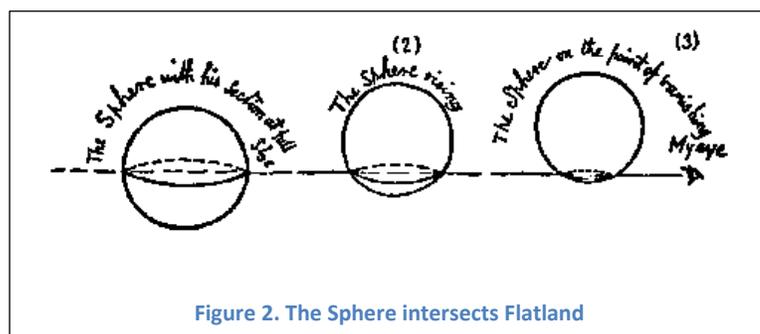

Figure 2. The Sphere intersects Flatland

Abbott's purpose is to use Flatland to make points — about mathematics to be sure, but more urgently about his society. His purpose, however, is not our purpose. Poor A Square's experience in Flatland and Spaceland, can viewed more generally to describe the failure of lower-dimensional creatures attempting to adequately reason about higher dimensions. We will use Abbott's work to illuminate the effects of adding an extra dimension, not of space but of cyber, to our world, and to contrast the intuitions suggested

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[†] Flatland is Public Domain, and many editions are available. Page references here are to the Roberts Brothers (Boston) edition of 1885, as it has been digitized by Google and is widely available.

[‡] Abbot in Part 1 is primarily concerned with class structure; very much like Gulliver's Travels, Part I of Flatland should be read as a satirical commentary in which A Square plays the same role as Swift's Lemuel Gulliver.

[§] There are also visits to Lineland and Pointland, but we shall pass over these here in the interest of space.

by this extra dimension metaphor with those suggested by the existing DoD domain metaphor. To that end, let us explore three characteristics of Abbott's *Flatland* in more detail.

Characteristic 1: Spaceland cannot really be apprehended in Flatland

The inability of inhabitants of lower-dimensional spaces to fully apprehend higher-dimensional ones is one of the most strongly-urged propositions in *Flatland*. Abbott actually divides it into two closely-related claims. The first is that appearances when projecting down from higher-dimensional spaces can be deceptive. Thus, when Square's wife first sees the Sphere, she mistakes it for a woman, as its projection viewed within the plane is a straight line [8 p. 105]. Similarly the Sphere explains to A Square that it will appear in Flatland to be a collection of circles, growing or shrinking over time, as shown in Figure 2 [8 p. 113].

The second claim is more fundamental – that it is impossible for lower-dimensional beings to really understand higher-dimensional worlds. This Abbott makes repeatedly, most strongly in his visitation by the Sphere ("All that I could ***comprehend*** was, that the circle had made himself smaller and vanished…" [8 p. 114], but also in the visits to Lineland and Pointland, which we have mentioned only in a footnote. Only when the Sphere bodily yanks A Square out of his two-dimensional world can Square comprehend the third dimension.

> "I looked, and behold, a new world [8 p. 122]!"

At least as bad, once A Square returns to Flatland, his ability to imagine the Third Dimension fades away with time, so that by the end of the book, he can say "…there are seasons of mental weakness, when Cubes and Spheres flit away into the background of scarce-possible existences; when the Land of Three Dimensions seems almost as visionary as the land of One or None… [8 p. 155]."

Characteristic 2: Spaceland denizens can appear and disappear in Flatland when and where they choose to

Spaceland acts and Flatland reacts, because the choice of when to intersect the z=0 plane is entirely up to the former. (Although the Sphere appears at the beginning of the Third Millennium because he is allowed to do so only once every thousand years [8 p. 118], that restriction is imposed by Spaceland, not Flatland.) The Sphere appears without warning in A Square's house [8 p. 105], and again in the Grand Council [8 p. 119], pursuing his own designs. Similarly, he can depart in spite of the best efforts of Flatlanders to detain him. "'We have him,' they cried; 'No; yes; we have him still! he's going! he's gone [8 p. 129]!'"

Those frustrated cries of the Flatland police could as easily apply to cyber defenders, for threats can appear from cyberspace willy-nilly, at a time and place of the attacker's choosing. Furthermore, the adversary can disappear from the physical world's three-dimensional hyperplane (which we have been referring to as 'cyber=0') and back into cyber at a time of his own choosing. (We concede that artifacts of code may be retained, but the attackers themselves are not subject to capture in the sense that physical attackers are.

Indeed their very identity is dishearteningly hard to pin down, as will be discussed below.) Adopting the dimension metaphor for cyber in preference to the domain metaphor radically changes one's conceptualization of the issue, focusing attention of threat containment, management, and resilience rather than exclusion. Viewing cyber through the Flatland lens emphasizes that complete exclusion of an adversary is an unreasonable goal.

Characteristic 3: Nothing in Flatland is hidden from Spaceland

Early in his conversation with A Square, the Stranger from Spaceland points out "…your houses, your churches, your very chests and safes, yes even your insides and stomachs, all lying open and exposed to my view [8 p. 110]." Then he proceeds to demonstrate this, by taking a tablet of accounts from a "locked" box and moving it to the other corner of the room [8 p. 119].

Here the application of the dimension metaphor to cyber is so obvious that it hardly needs to be made explicit. Any number of organizations, from Sony to Equifax to the Democratic National Committee can testify that their secrets are "all lying open and exposed to [cyber denizens'] view." Again we see the utility of viewing cyber through the *Flatland* lens. The dimension metaphor emphasizes that the prevention of data exfiltration, as well as adversary exclusion, is impossible, in a way that the domain metaphor does not.

Dimension as Metaphor, Redux

Abbott believed the first characteristic of Flatland the most important, but its metaphorical implications with regards to cyber are not as clear cut as those of the other two, so we will take a few sentences to tease them out with respect to each of the two related claims we have mentioned. The first claim, deceptive appearances, closely parallels the cyber problem of attribution. Things need not be what they appear in Cyberland, and identities may be easily spoofed. Just as the true nature of the Sphere can only be inferred in Flatland by sensing a set of growing and shrinking circles over time, so must Cyberland entities be laboriously tracked over time and networks in order to infer their true nature.

The second claim derives its relevance to our understanding of Cyberland, as it does A Square's understanding of Spaceland, due to the perceptual limitations of lower-dimensional beings. In our physical world, our senses have evolved to perceive threats directly. But we cannot perceive packets; our perception of cyber is entirely synthetic, through sensors which we place out in Cyberland and whose outputs we route back into the cyber=0 hyperplane of Spaceland. The "I looked, and behold, a new world" moment A Square experienced will forever elude us. How should this aspect of cyber as a dimension affect our intuitions? First, it emphasizes that sensors, their placement and development, are an extremely important avenue for the future development of cyber operations. Second, it suggests that non-human entities native to Cyberland in the same way that the Sphere is native to Spaceland should evolve to play a more important role. Neither of these two insights is particularly obvious if cyber is considered merely as another domain of military operations.

When the Metaphor Breaks Down

So far we have used our dimension metaphor and the comparison to Flatland as a mode of critiquing the DoD's prevailing domain of action model for cyberspace[**]. However, like all metaphors, cyber as an additional dimension has its limits, and the *Flatland* analogy can lead one astray. Here we list a few problems with the Flatland metaphor as applied to cyber, divided into two groups: where the metaphor leads to overly pessimistic conclusions, and where it leads to overly optimistic ones.

Things are better than they seem

We're all in the same boat. The Sphere is a true three-dimensional creature, looking down at a two-dimensional world. Seen from within Flatland, he can teleport, disappear, and appear at will, and he possesses perfect information. However, our adversaries are three dimensional and physical. They have the same problems in Cyberland that we do: poor visibility, poor information and attribution, poor sensors, and all the rest. They do not possess the overwhelming advantages of the Sphere.

Things are worse than they seem

On the other hand, some cyber aspects make the Cyberland situation even worse than the Flatlanders experienced. First, although the building blocks of the physical world are atoms, the building blocks of cyber are bits.[††] Bits are more ephemeral and mutable than atoms. In Cyberland, armies of VMs or containers may be rapidly created, destroyed, replicated, and moved around in a way that people and other physical assets in Spaceland cannot. (E.g. the Sphere cannot deform itself into a Torus, nor quickly generate a dozen replica Spheres.) Second, although it may be possible to define some sort of distance metric for cyberspace, it is certainly not the Euclidean metric most of us (including Abbott) are familiar with, and which prevailed across all of Flatland. Instead, it is likely to be abstruse, non-intuitive, and graph-based, thereby complicating any idea of motion or maneuver in cyberspace and frustrating desires to transfer over the familiar mapping paradigm of physical space to cyber. Third, and perhaps most important, the Sphere was not a malicious actor; he was trying to be helpful. The presence of malicious adversaries, for which cyber was not designed, is perhaps the most characteristic feature of Cyberland, as opposed to Spaceland.

Implications of the Metaphor

Early in this short essay, we pointed out that the choice of metaphor influences our reasoning processes; this fact served as the basis for urging the superiority of dimension over domain as a metaphor for cyber. We wish to return to it. A domain-based metaphor encourages us to consider cyber "security incidents" as particularized events with specific "root causes" which can be mitigated with proper care. The Flatland metaphor, in contrast, suggests that cyber adversaries' ability to appear at will (Characteristic 2) and take

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[**] Note we do not believe that DoD's domain metaphor is the only bad mental model in cyber; it is merely the one we are examining here.

[††] The author is indebted to his colleague Jeremy Mineweaser for this trenchant formulation of the issue.

whatever they want (Characteristic 3) are intrinsic qualities of their existing in the higher-dimensional space in which our physical world is currently embedded. One would thus naturally begin thinking about cyber with this mindset. In this view, Sony can no more expect to keep its emails secret than can the Grand Council expect to keep the Sphere out of its Council Chamber.

The preceding may appear to be a counsel of despair. Indeed, since the cyber dimension appeared relatively recently, some advocate retreating to pre-cyber technologies (typewriters, carbon paper, relay logic, point-to-point wiring) for anything really important, thus effectively excluding it [9]. We wish to take a less hopeless point of view, and consider more carefully Characteristic 1. Just as understanding Spaceland is impossible from within Flatland, understanding Cyberland is impossible from within Spaceland. Although we created Cyberland, being flesh and blood, we are not cyber natives. We are condemned to be foreign visitors with only tourist visas. We discussed synthetic perception and the need for sensors above. However, even if the perception problem could be ameliorated through smart sensor development, we would still be faced with the timescale issue: human timescales are longer than cyber ones by many orders of magnitude. We suggest that another important insight that the cyber as a dimension versus domain metaphor provides is that the only realistic way of dealing with operations in cyberspace is the creation of cyber natives: digital beings which combine native perception with autonomous decision-making power at the cyber-relevant timescales. DARPA's recent Cyber Grand Challenge represents a first step in that direction, but only a small one. A close reading *Flatland* suggests we need to build our own Spheres: a corps of semi-autonomous and bit-based cyber natives with artificial intelligence, who would report back to humans on a human-centric timescale what they had seen and done on our behalf in Cyberland.

Conclusion

As Johnson and Lakoff say, "…metaphor is pervasive in daily life, not just in language but in thought and action." [7 p. 3] Thus, faulty metaphors lead to faulty thoughts and faulty actions. We have argued that this is the case in cyber, and specifically that the DoD's domain metaphor, while proposed as a superficially attractive parallel to previous warfighting domains, results in conceptual false steps. We suggest that a metaphor of cyber as an additional dimension which touches all the existing domains everywhere is preferable. Not only is it preferable in theory, but leads to significantly different approaches to cyber in practice.

These approaches have been explored here in an appropriately metaphorical fashion, by mining the 19th century novella *Flatland* for parallels and insights. *Flatland* explores conceptual failure as lower-dimensional beings are confronted with higher dimensions. Our critique of the domain metaphor from a *Flatland* vantage point yields the following insights which follow organically from a dimension metaphor, but not from a domain one:

- Complete exclusion of an adversary is impossible
- Data is always available for the taking
- Attribution is difficult, and shape-shifting is the norm

- Direct perception of the cyber dimension is impossible, and any cognition at all difficult
- And, finally, cyber adversaries are regrettably not bound by Spaceland's once-per-millennium visitation policy.

Acknowledgements

Funding

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