Brain-Universe Mapping: The Astonishment of Connection
Dana W. Paxson
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Most of us like to operate in a little patch of the universe, a bit like a farmer working an acre of land, feeding the family, tending the crops, sniffing out the weather and the seasons, living the comfortable rhythm of a life with a good fence, good water, and good air. Our crops include philosophy, sciences, trades, crafts, and arts. We go to market with our harvests, we return with what we need. It is good.

Along comes the Web. Our fields explode into entire planets, our crops into jungles; our fences fall in tangles with each other; our families take off on wild, scattered stunt flights; our water and air take on colors and shapes and tastes and smells, lurid and tempting; our jungle harvests arise to commit crimes of passion with each other, birthing indescribable offspring; we scrabble, floating in the mighty chaos of change embracing and devouring every one of us.

How do we make our way in such disorder? Douglas Adams characterized the situation nicely in his fiction, when an elderly woman looks out the window during a high-altitude airline flight to see a couple making love on the wing of the plane:

“She was mostly immensely relieved to think that virtually everything that anybody had ever told her was wrong.”

Trying to find our ways, we are making maps of everything, all the time, everywhere, in every way. This is what we call learning. Making maps has become our moment-to-moment obsession as we flounder in the constantly-changing medium of our ‘lifescape’. Once long ago learning was supposed to be a stage of life. Now learning – mapping knowledge for ourselves – is an unending process like breathing or digesting. We don’t stop learning any more than we stop breathing, because the consequences are dire.

Images are maps. An image translates light rays from our world into its own space. The instant we open our eyes for the first time, we begin mapping the universe around us into our eager, overpopulated, infant brains. We annotate our maps with sound, touch, taste, and smell. We adorn our maps with narrative.

We underestimate their power. Here you might get a taste of just how powerful our maps are, all encrypted neatly in our heads. The numbers and scales involved are staggering. We’ll start with two images at the small end of things, deep in the human brain. Out of necessity, we will oversimplify.

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1 from “So Long and Thanks for All the Fish”, by Douglas Adams
Here is a diagram\(^2\) of a single nerve synapse: a connector between brain neurons. On average there are perhaps a thousand synapses, each as complex as the one diagrammed here, for every single neuron in the human brain. Hold that thought.

How big is a brain neuron? It’s a cell, made up of a nucleus, an axon that sends out pulses of electricity, and a branching tree of dendrites that receive pulses of electricity. The synapses are the connectors between dendrites and axons of different cells.

\(^2\) from The Synaptic Organization of the Brain, 5\(^{th}\) edition, Gordon M. Shepherd, ed.
Now we take a step up in scale. Here’s an image\(^3\) of a single brain neuron in the neocortex, up in the brain’s layers just below the wrinkly surface. A single neuron.

Any one of the thinnest lines tracing out from the tangle you see here is a single dendrite, reaching out to connect via its synapses to other neurons in the brain’s network. That little flat bar at lower right represents a length of a tenth of a millimeter. So the whole tangle at the center is less than a millimeter across – about the thickness of a pencil lead.

Each of the many synapses on each dendrite, then, must be between one and ten millionths of a meter across. In the above image the synapses are too small to see.

When you pack all this biological wiring into our human brain, we arrive at about 90 billion neurons, averaging about 1000 synapses each, giving 90 trillion synapses of the complexity of the one diagrammed in the first image. Now we know a little about what we’re dealing with between our ears.

\(^3\) from *The Synaptic Organization of the Brain*, 5th edition, Gordon M. Shepherd, ed.
We can relate this in scale to our digital world nicely. If each synapse, with all of its chemical signaling abilities, could be fully described in one thousand bytes of storage on a computer, the total storage required just for the synapse descriptions would total $90 \times 1000$ trillion bytes: 90,000 terabytes – a whole lot of drives. But that’s a rather-severe underestimate, because describing the content, structure, and dynamics of one synapse would take a lot more than 1000 bytes of storage. And that’s just one synapse, in just one brain. The human brain is pretty impressive.

And the universe? Yeah, that’s pretty impressive too. You’ve all read about it: just under 14 billion years old, over 45 billion light-years across, every light-year about six trillion miles, over 170 billion galaxies in just the space we can see, each galaxy with between ten million and one hundred trillion stars in it, you know the drill. We’ve already got maps of the universe, at least the parts of it we can see with all our electromagnetic senses. These are three-dimensional maps. We can fly through them, thousands of light-years in seconds, color-codings to signal us about what we are seeing, our own Milky Way galaxy nothing but a lost dot in the vastness.

These maps are all a gift of our new digital reality. Here in this frame from a fly-through animation4, ‘Home’ marks our galaxy, the green dot above the ‘H’. That green dot marks more than 100 billion stars packed loosely in our entire Milky Way. One of those invisible stars is our Sun.

At bottom right is another green dot, this time for the great nebula in Andromeda, which we see in the sky from our place in ‘Home’ as a smudge of light.

The green dots are all galaxies in the Local Group of galaxies in the Virgo Supercluster. The dots of other colors are all members of other galactic clusters, many millions of light-years out.

We’ve mapped millions of them, all stored away in software tables, and we cruise among them like the gods of time (or the Timelords, if you prefer). Here’s the video of the journey:

We’ve given names to the galaxy clusters and superclusters, much the way we’ve named everything else from our brain regions to our Internet host systems. Here’s a map\(^5\) where you can see how the Virgo Supercluster, with us deep inside it, nestles in the relatively-local neighborhood of our universe. We’re near the middle of the map here.

Since we’re so provincial in our tiny patch of space, we created most of these names from the Milky Way constellations we have to look through with our telescopes to find the galaxy groups. This two-dimensional image map doesn’t reflect the incredible richness of structure of

\[\text{http://upload.wikimedia.org/wikipedia/commons/d/d8/Nears.jpg}\]
the whole thing. The walls, voids, clusters, and strands here measure in the hundreds of millions of light-years. Every single white speck in the image contains billions of stars.

With all its wisps and specks, and with its colors turned inside out, the above image resembles the diagram\(^6\) below. This image charts a good part of the World Wide Web. It was produced in 2005, so by now it’s even less of the whole picture.

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\(^6\) Partial map of the Internet based on the January 15, 2005 data found on opte.org. Each line is drawn between two nodes, representing two IP addresses. The length of the lines are indicative of the delay between those two nodes. This graph represents less than 30% of the Class C networks reachable by the data collection program in early 2005.
If these images resonate with that of the neocortical neuron presented earlier, it supports this point: we have in the Web the beginnings of an adequate map between the richness of our brains and the wealth of the universe in which we live. Our principal challenge appears to be that we find this richness in brain, Web, and universe so intimidating that we resist this advanced level of mapping. It feels like overload.

We fear the madness of knowing who and what we ourselves might really be.

Such advancement feels to us as inconceivable as flying with nothing but our extended arms, but we are doing it all the time, as unaware as a fish is unaware of the water in which it swims. We are creatures of the vast universal sea, and now, with our digital lines and links and circuits interpenetrating our beings, we are becoming magically and deeply aware.

The Web has opened our minds to make the greatest and most wonderful maps. Not satisfied with the kind of map we can make on a flat sheet or a globe, we now build, operate, and inhabit entire digital worlds in three dimensions, worlds such as Second Life and World of Warcraft; we conceive in our physics of underlying universal structure occupying many more dimensions than we can visualize directly as a whole.

But we can find our ways to connect all these things in our brains. You already know how to draw a flat picture of a square or a three-dimensional cube. We can draw flat pictures of hypercubes with many more dimensions. Here below is a flat picture\(^7\) of a nine-dimensional cube – an ‘enneract’ – where each line you see is from one corner to another adjacent corner. A lace web of pure pattern.

Did our species spend its precious time and energy on things like this before we all gained access to the knowledge and tools to build it using the Web? Should we? Can we? From brain to Web to universe, our maps resonate with connections. Until the digital world engulfed us all, we lacked the medium and tools to see the map of the maps: the way in which maps of aeons and light-years, maps of microseconds and Internet nodes, and maps of milliseconds and dendritic synapses could all be seen to match one another in surprising ways.

Here’s one final map. Researchers working with monkeys on vision managed to map out exactly how the eye maps what it sees into the cells of the brain. It turns out to be pretty straightforward. You see it, and your brain maps it into its own cells, just as if it were a mapmaker copying point-by-point from the visual field (A) to the switchboard of the brain’s lateral geniculate nucleus (B) and on to the primary visual cortex (C). Put galaxy specks where you put Internet nodes a moment later – it’s all just one map your brain makes. So it’s all in our heads. Or is it?

Do we want to map our whole universe into our brains, and our brains out to dance with the universe? Yes! Ninety trillion synapses, ninety billion neurons? Yes, I think we’re up to the job. Plunging into the Web, we are boldly launching our brains on this ultimate voyage, and our minds, our world, our universe will never again be the same. We are becoming astonishment itself.

‘... ponder over the completeness of the creation of man: all these worlds and all these grades are enveloped and concealed within him. “Dost thou think thy body a small thing, while in thee is enfolded the universe?”’

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8 from http://fourier.eng.hmc.edu/e180/lectures/v1/node3.html
9 from “The Seven Valleys”, by Bahá’u’lláh