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Cours Géométrie Différentielle

14h00 – 14h45

The topology of neuronal firing rate space

If the firing of a neuron is convoluted with the duration and intensity of its consequence, it becomes a continuous variable, the firing rate. The firing of a class of n neurons is described by a curve (the experiential curve) moving in a n-dimensional space. However, not all combinations of firing occur. I argue that the dimensionality of most classes of neurons is very low, that many are 1- or 2-dimensional, and that we can describe the topological structure of these low dimensional structures I use the term "dimension" to refer to something that changes continuously, in contrast to much usage, especially in psychology.

I show that the firing in sense organs and in the early stages of processing, (including primary sensory cortex of visual, cutaneous, and auditory sensory systems) has a nontrivial bundle structure, with a base that is due to movement of sense organs and a fiber that is due to movement of sources. A projection of the sense organ base from the sensory bundle describes place cells of the hippocampus, head direction (yaw) cells of postsubiculum, and pitch and roll cells in the vestibular system. These projections describe movement of sense organs in absolute space. The fiber of the bundle occurs as a restricted projection of the sources that are singled-out (i. e. the objects of attention), for vision in inferotemporal cortex and other association cortex. The sense organ base of location and orientation has a tangent space in dorsal MT cortex and the restricted projection of the fiber has a tangent space in MT cortex.

The firing in each neural class can be described as a manifold. Some coordinate charts cover the whole manifold and some manifolds (mostly interoceptors) have only one covering coordinate chart. Some coordinate charts hold only locally and overlap other coordinate charts, so that a single source may be defined by multiple replaceable cues. Low dimensional manifolds embedded in a much higher firing rate space are intrinsic space.
Firing rate space is an extrinsic space.

The experiential curve can only intersect itself if it occurs in a 1- or 2-dimensional manifold. This is the sense in which an experience can recur.

Neural classes affecting other neural classes are described as maps between manifolds. The same firing of a neuron can be caused by many different inputs and a neuron or class of neurons cannot distinguish different inputs that cause the same consequence. Said another way, a neural class defines an open set of its input (the topology of the input) in terms of what causes an open set in the image, the inverse image topology. In the inverse image topology all maps are homeomorphisms and homeomorphisms with a common range or domain can be composed. Therefore, in sensory systems the open sets of projections and restricted projections from sensory bundle define open sets in the perceived world and the neural apparatus in between is invisible to brain. A forward topology from motor and motivational systems can be defined in an analogous way, The inverse image and forward topologies gives the "point of view from inside brain".

One manifold can be a local coordinate chart of other manifolds. The way that these open sets of other manifolds are glued together as coordinate charts gives topological structure to the recipient manifold. The same open sets can define different structures in different manifolds (e. g. location, yaw, and a singled-out-source, all using the same open sets from a manifold of the singled-out-source).
The embedding of a manifold in firing rate space may change due to development, pathology, learning, substitution of overlapping coordinate charts, and variance. Not all changes in neural activity can be described by movement of the experiential curve in low dimensional

manifolds. Some change in activity is due to change in embedding. Motivational and motor systems are described as dynamical systems, but are not discussed in this presentation. The cerebellum causes a change in motor embedding. A change in motivational embedding is, among other things, a change in emotion.

	extrinsic space	intrinsic space
usual topology	physiology	behavior
inverse image or forward topology	psychophamacology neuropsychlogy	mind

The four descriptions describe the same thing in different ways.

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