Dynamic Field Theory
Part I: continuous spaces and activation fields

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Discrete “neurons”

- or activation variables: how do they arise?
  How do they sample sensory/motor spaces...

- no evidence that neural discreteness matters for behavior
Continuity in space

- hypothesis: behavior is embedded in continua
  - the space of possible behaviors, e.g. space of movements, percepts, timing structures
  - neuronal substrate is continuous (maps, broad tuning)

(=> need to understand how categorical behavior may emerge from such continua)
Dynamical Field Theory: space

- In DFT, continuous spaces are dimensions over which activation fields are defined.
  - Homologous to sensory surfaces, e.g., visual or auditory space (retinal, allocentric, ...)
  - Homologous to motor surfaces, e.g., saccadic end-points or direction of movement of the end-effector in outer space
  - Feature spaces, e.g., localized visual orientations, color, impedance, ...
  - Abstract spaces, e.g., ordinal space, along which serial order is represented
example: motion perception

- continuous motion
- apparent motion
- motion pattern
example: selection decisions in motion perception

- motion pattern
  - why not diagonal motion?
  - or the other diagonal motion?
  - => motion pattern perception involves selection decision
example: selection decisions in motion perception

can the alternative motion pattern be realized?

- flat motion quartet
- tall motion quartet
- square motion quartet
space of possible percepts and activation field
space of possible actions and activation field
fields: continuous activation variables defined over continuous spaces
activation fields

- Information, probability, certainty
- Activation field
- Metric contents: e.g., space, movement parameters, feature dimensions, viewing parameters, ...
- Specified value
- No value specified
representing different percepts

movement direction $\phi$

$u(\phi)$
Link between DFT and neurophysiology

What do neurons represent?
tuning curve

- example: primary visual cortex (monkey)
tuning curve

example: primary motor cortex (monkey)
Link between DFT and neurophysiology

Example 1: Jancke et al: A17 in the cat, population representation of retinal location

Jancke, Erlhagen, Dinse, Akhavan, Giese, Steinhage, Schöner JNsci 19:9016 (99)
- determine RF profile for each cell
- it's center determines what that neuron codes for
- compute a distribution of population activation by superposing RF profiles weighted with current neural firing rate
The current response refers to a stimulus experienced by all neurons.

Reference condition: localized points of light.
result: population distribution of activation defined over retinal space = representation of visual location
=> does a decent job estimating retinal position

current stimulus: square of light

range of retinal field sampled by neurons

△ 0.4°
- Extrapolate measurement device to new conditions
- e.g., time resolved

Two different stimulus locations

30 - 40 ms  40 - 50 ms  50 - 60 ms  60 - 70 ms  70 - 80 ms

[Diagram showing spatial and temporal activation changes across different time intervals]
or when complex stimuli are presented (here: two spots of light)

response to composite stimuli

increasing distance between the two squares of light

superposition of responses to each elemental stimulus

□ 0.4°
by comparing DPA of composite stimuli to superposition of DPAs of the two elementary stimuli obtain evidence for interaction

- early excitation
- late inhibition
interaction

activation level in DPA
at location of left component stimulus

response to composite stimuli
superposition of responses to each elemental stimulus
evidence for inhibitory interaction
time
model by dynamic field:

stimulus  experiment  DFT model
Neurophysiological grounding of DFT example: movement planning

Bastian, Riehle, Schöner, 2003
tuning of cells in motor and premotor cortex to direction of end-effector movement path
Distribution of population activation = \( \sum \text{tuning curve} \times \text{current firing rate} \)

[Bastian, Riehle, Schöner, 2003]
look at temporal evolution of DPA or DPAs in new conditions, here: DPA reflects prior information
Distributions of Population Activation are abstract

- neurons are not localized within DPA!
- cortical neurons really are sensitive to many dimensions
  - motor: arm configuration, force direction
  - visual: many feature dimensions such as spatial frequency, orientation, direction...

=> DPA is a projection from that high-dimensional space onto a single dimension
... back to the activation fields

- how do we arrange that a field is “defined” over the appropriate dimension?

- => by its input/output connectivity...