A spiking neuron model of movement and pre-movement activity in M1

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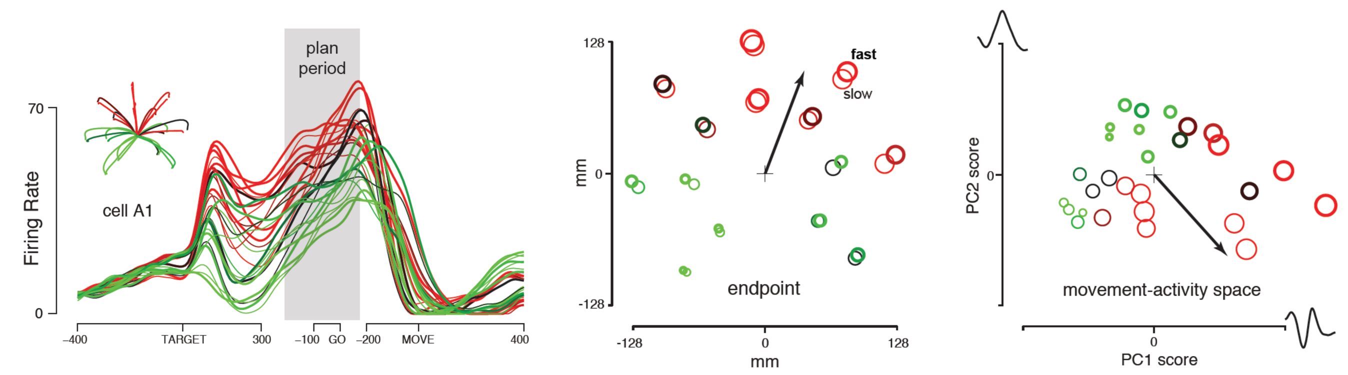
Introduction

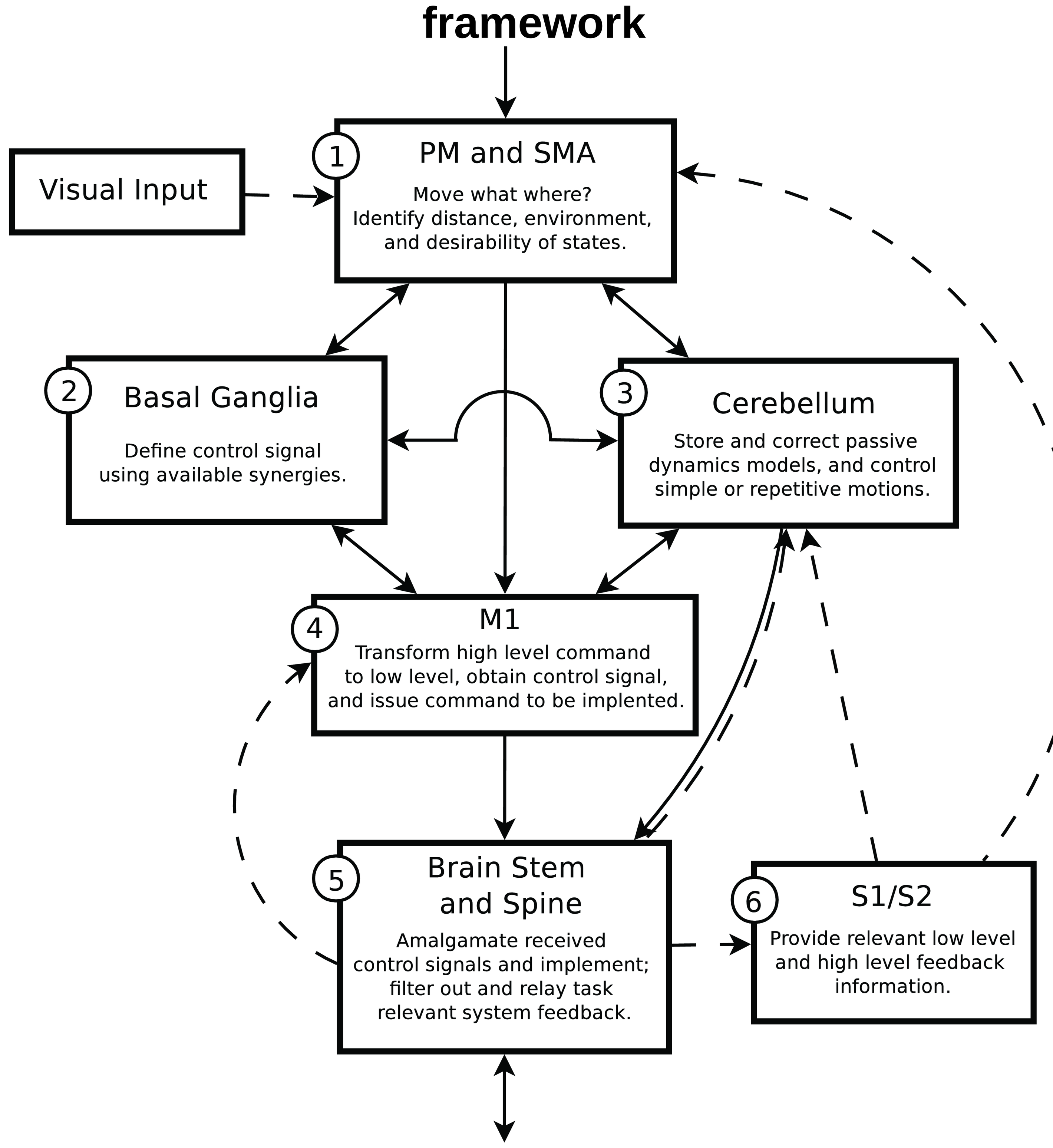
- Monkey motor cortex recordings show pre-movement convergence of neural activity, but highly non-linear activity during movement execution[Chuchland2010]
- This activity was analyzed as a direct, complex mapping between neural activity and movement



Goal

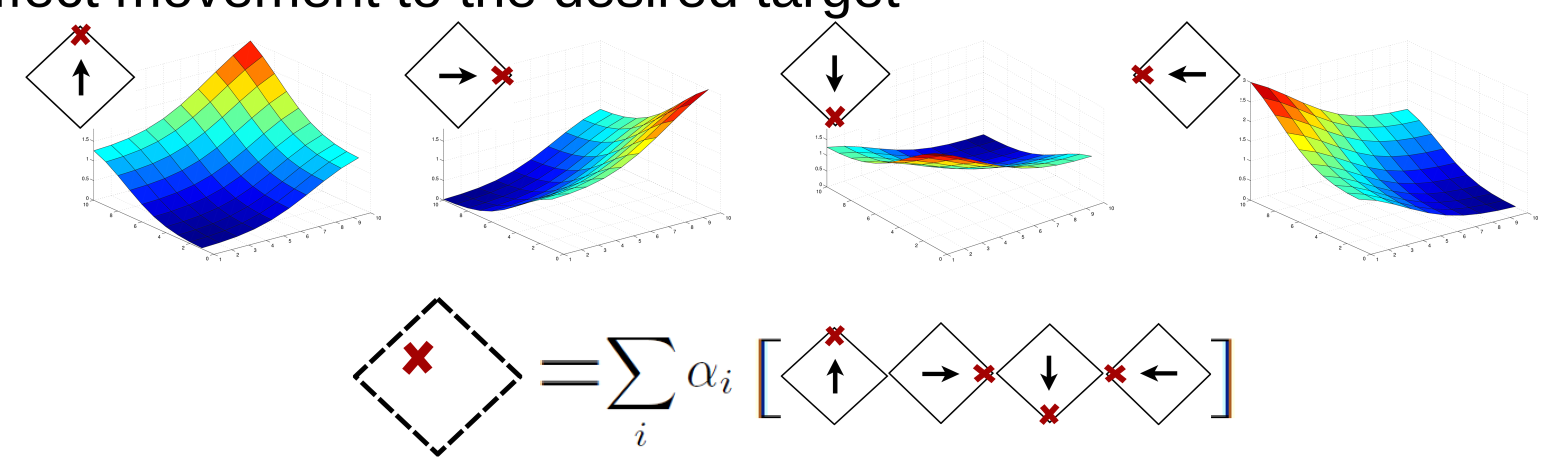
- Explain neuron responses with a simple mapping between control signals and neural activity, and functionally derived control signals

Neural Optimal Control Hierarchy (NOCH) framework

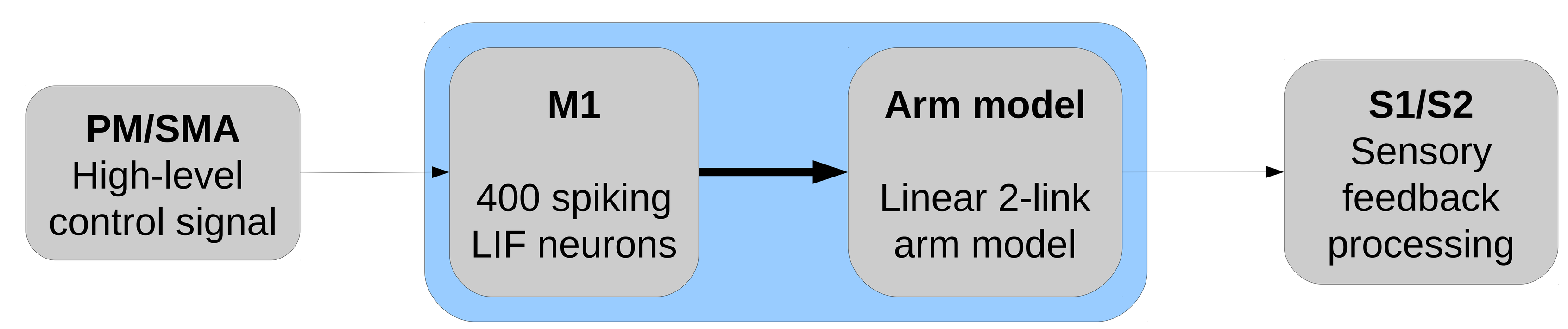


Spiking neuron model of M1

- The model represents three layers of the motor hierarchy
- High-level control signal based on learned actions, weighted to effect movement to the desired target



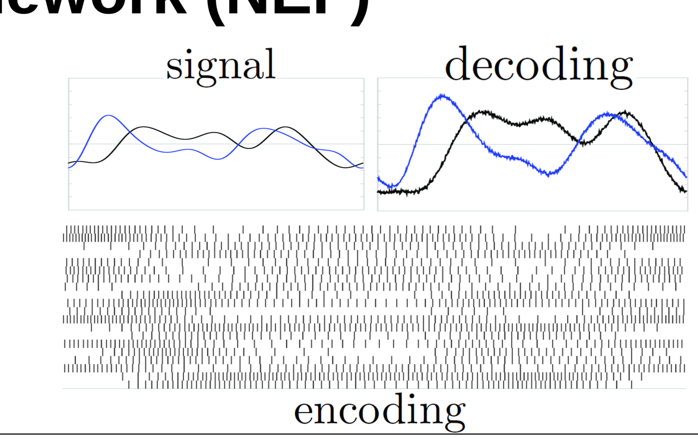
- Low-level control signal created to match the system movement specified by the high-level as best as possible



Neural Engineering Framework (NEF)

Encoding: $a_i(\mathbf{x}) = G_i\left[\alpha_i\langle\mathbf{e}_i\mathbf{x}\rangle + J_i^{bias}\right]$

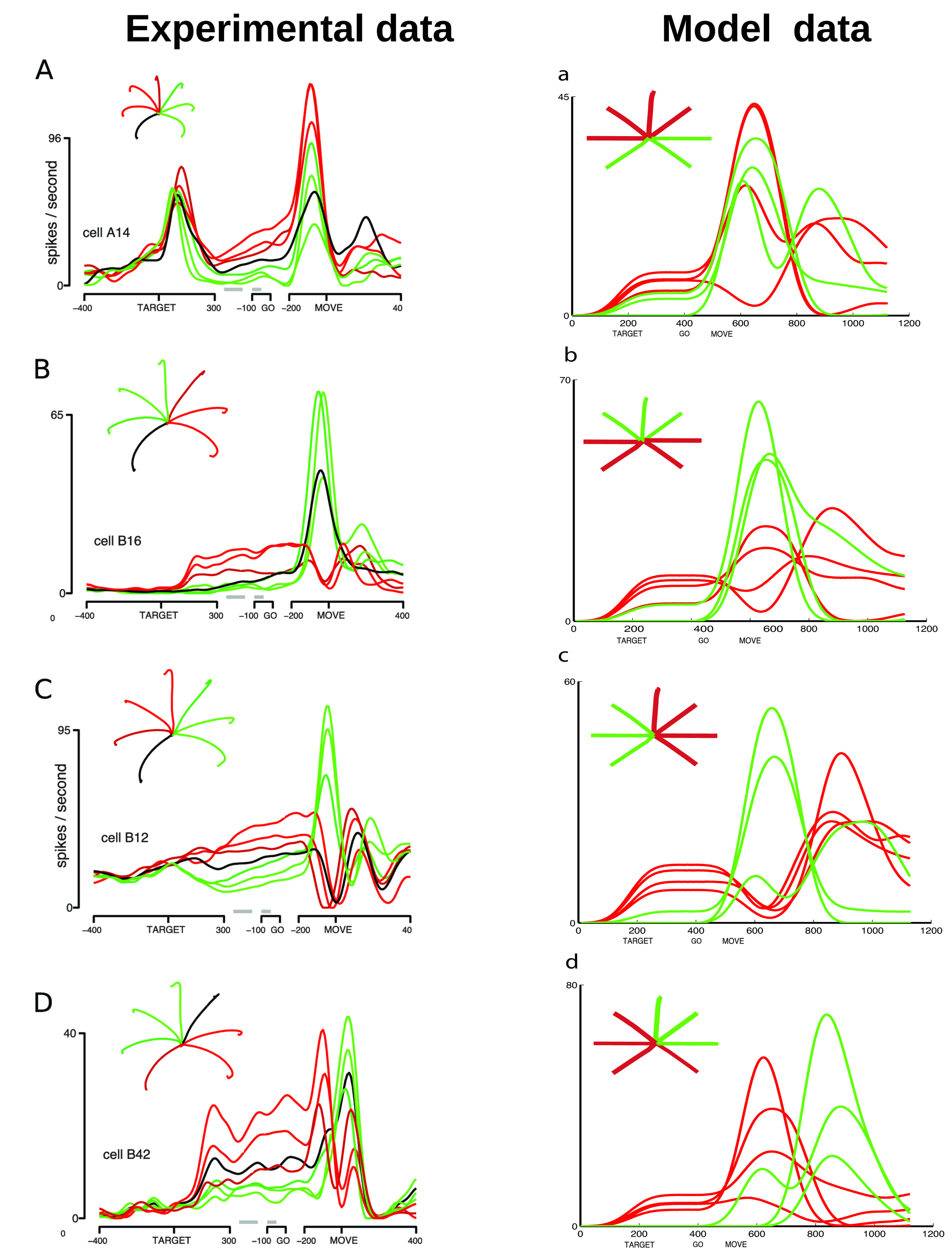
Decoding: $\hat{\mathbf{x}}(t) = \sum_{i,n} h(t - t_{i,n})\mathbf{d}_i$



The Neural Optimal Control Hierarchy (NOCH)

1. Target(s) specified in high-level, low-dimensional space; visual input incorporated, identifying distances and object locations
2. Optimal action is specified as a summation of weighted movement components (motor synergies)
3. Task-relevant internal model of system dynamics retrieved, control signal adapted for current context
4. High-level commands issued to M1; M1 transforms high- to low-level commands ; BG maps low-level command to synergies
5. Inertial information and motor plan corrections are added to the motor command by the CB. Error correction signal from CB applied to descending control signals, internal models updated
6. Task-relevant low-level feedback sent to M1 and CB from S1; in S2 feedback is transformed to a high-level signal and sent to the PM & SMA

Results



Conclusions

- The complexity of the neural response can be understood as a simple mapping between neural activity and control space, combined with the output of an optimal controller.
- Distinguishing representations from dynamics can help clarify the contributions of each to observed neural responses.
- To characterize dynamics, a high-level view that combines optimal control and biological constraints provides a good foundation (e.g. NOCH).