Inhaltsverzeichnis

1 Formeln

- CLIAF (Neftci 2011):

  $C_m \frac{\mathrm{d}}{\mathrm{d}x} V_m = I_{in}(t) - \beta + I_{fb} e^{\frac{\kappa}{U_T}(V_m - V_{th})}$

- Axon-Hillock IAF (Mead 1989)

  $C_m \frac{\mathrm{d}}{\mathrm{d}x} V_m = I_{in}(t) - \beta, \quad V_m(t) \in (0, \Theta)$

- Hodgkin-Huxley ()
- AdEx ()

2 Einheiten

- β - Konstanter Leckstrom
- $I_{in}(t)$ - Neuronaler Inputstrom

3 Abkürzungen

AER - Address Event Representation
CCN - Cooperative and Competitive Network
CLIAF - Constant Leaky Integrate And Fire neuron
DNC - Digital Network Chip
DPI - Differential Pair Integrator
EPSC - Excitatory Postsynaptic Current
FPGA - Field Programmable Gate Array
HH - Hodgkin Huxley neuron model
HICANN - High Input Count Analog Neural Network
IAF - Integrate-and-fire neuron model
ISI - InterSpike Intervall
LTD - Long Term Depression
LTP - Long Term Potention
LTU - Linear Threshold Unit
STDP - Spike Timing Dependent Plasticity
sWTA - Soft Winner-Take-All Network

4 Definitionen

- AER: Communication Protocoll which describes spikes from sources
- overconstrained: equations outnumber the unknowns
- raster plot: spikes of neurons plotted in time

5 Bekannte Forscher

- Emre Neftci, Elisabetta Chicca, Giacomo Indiveri, Rodney J. Douglas
- Kwabena Boahen
-

6 Notizen zu wichtigen Arbeiten

6.1 Neftci 2010: A Device Mismatch Compensation Method for VLSI Neural Networks

- transistor properties mismatch as major VLSI problem
- mismatch compensation algorithm through connectivity
- no layout disadvantage (no extra HW memory)
- exploits Address-Event Representation
- metaplasticity as homeostatic mechanism for homogeneous population response
- change connectivity profile (# or %) to normalize response strength
- test: sWTA as possible general purpose structure
- synaptic scaling method to normalize response of VLSI sWTA with HW respresentation and constraints (e.g. spiking output)
- synaptic circuits with linear filter (1st order) to summarize different sources
- 1 synapse emulates synapses with same time constant and weight $\rightarrow$ modulates coupling strength between populations
- test of theory with sWTA and an compensation matrix $\rightarrow$ up to 40% less variability and same mean in transfer function
- fig 1: bumps getting homogeneous after compensation (reduced mismatch)
- increased discrimination performance: generally better win rate of stronger input population

6.2 Neftci 2011: A Systematic Method for Configuring VLSI Networks of Spiking Neurons

- motivation: subthreshold transistor $\rightarrow$ small signal $\rightarrow$ prone to noise and mismatch
- motivation: high-lvl program language needed $\rightarrow$ auto determining of biases taking mismatch in account
- motivation: determining bias voltages corresponding to model params through iterative search $\rightarrow$ resource and time consuming & no predictive power (must be executed afer every param change)
- automatic bidirectional parameter mapping technique (high-level NN simulation $\leftarrow\rightarrow$ VLSI)
- algorithm is general and usable if LTU behaviour approximated in circuit (IAF for example) / if regime that can be modeled using mean-field approach
- approximation possible if a regime exists in which neurons have threshold-activation linear function (e.g. CLIAF)
- algorithm: standart parameter translation + determining bias voltage (one calibration for futuer uses)
- LTU $\leftarrow\rightarrow$ CLIAF model $\leftarrow\rightarrow$ VLSI spiking neuron
- drawback: to calibrate and build parameter translation detailed knowledge of circuit needed
- drawback: LTU approximation only works if $\tau_{syn} \gg T_{ISI}$

- Equations (2.5)+(2.6) as complete approximated description
- Equation (2.7)+(2.8) as bridge between LTUs and silicon neurons
- Equation (2.9)+(2.8) as specified CCN transfer output
- LTU approximation is accurate for setting gain and predicting steady state mean firing rate
- τ of hardware and software identical
- exact VLSI sWTA tuning possible

6.3 Neftci 2013: Synthesizing cognition in neuromorphic electronic systems

- motivation: reliable behavioural dynamics of noisy neurons needed
- (1) mapping hardware $\rightarrow$ abstract model (2) create sWTA (3) create sparse connections between populations to form soft state machine
- reliable state processing through active gain, signal restoration (memory), multistability (binary)
- neuromorphic agent as autonomous entity, observes (sensors) and acts (effectors) on context/stimuli, strives for abstract goal
- behavioural dynamics instead of programming logic
- 3 layers: high-level behaviour model, abstract computational (sWTA), analog-digital hardware
-

6.4 Sheik 2011: Systematic configuration and automatic tuning of neuromorphic Systems

6.5 Gao 2012: Dynamical System Guided Mapping of Quantitative Neuronal Models Onto Neuromorphic Hardware

6.6 Grassia 2011: Tunable neuromimetic integrated system for emulating cortical neuron models

6.7 Brüderle Dissertation 2009: Neuroscientific Modeling with a Mixed-Signal VLSI Hardware System

6.8 Brüderle 2011: A Comprehensive Workflow for General-Purpose Neural Modeling with Highly Configurable Neuromorphic Hardware Systems

6.9 Schwartz Dissertation 2011: Reproducing Biologically Realistic Regimes on a Highly-Accelerated Neuromorphic Hardware System

7 Mögliche wichtige Arbeiten

- determining unknown parameters and state variables of physical systems by measurements of a limited number of observables (parameter estimation methods)
- Brillinger 2008
- Keat, Reinagel, Reid, Meister 2001
- Paninski, Pillow, Simoncelli 2004

- Okatan, Wilson, Brown 2005
- Huys, Ahrens, Paninski 2006
- Abarbanel, Creveling, Farsian, Kostuk 2009

8 Notizen

- iterative Parametersuche kann durch Heuristik verbessert werden
  (Russel, Orchard, Etienne-Cummings 2007)
- IAF sind strombasiert
- Das erste IAF Modell ist das Axon-Hillock Modell von Mead
- Das A-H-Modell nutzt einen konstanten Strom als leak statt Konduktanz
- LTUs sind simple Modelle, die keine Spikezeitinformation und nichtlineare Elemente beinhalten
- der positive Feedback von CLIAF kann vernachlässigt werden, wenn der Threshold so gesetzt ist, das der ISI gleich bleibt
- man kann τ_{refrac} und Pulsweite ignorieren falls beide $\ll T_{ISI}$
- falls $\overline{T_{ISI}} \ll \tau_{syn}$ fluktuiert der Synapsenstrom um konstanten Wert $\sim w, f_{ISI}$
- Synapsen werden oft als Tiefpässe realisiert
- viele Annahmen bei Berechnungen $\rightarrow$ verringerte Komplexität $\rightarrow$ analystisch lösbar
- Nicht vorhandene Parameter mit nichtlinearen Abhängigkeiten müssen experimentell bestimmt werden
- Arten von Kalibration: Brute-force, ad-hoc, software (mismatch unbeachtet), suche um manuell bestimmte Operating Points, hybride
- Fehlerarten: Hardware-Nonlinearities, Transistor Mismatch, Kalibrationsungenauigkeiten

9 Kleine nützliche Wortsammlung

- parameter estimation/extraction/translation/mapping
- parameter space
- population activity measurements
- abstract computational layer
- mean field approach
- context-dependent task
- derivative - Ableitung
- inferred - von etw. abgeleited
- prohibitive - untragbar
- regime - Charakteristik
- coherently - folgerichtig, schlüssig, kohärent
- cognition - Wahrnehmung, Erkennung
- Synthese - Zusammenführung zu einer Einheit oder künstliche Herstellung