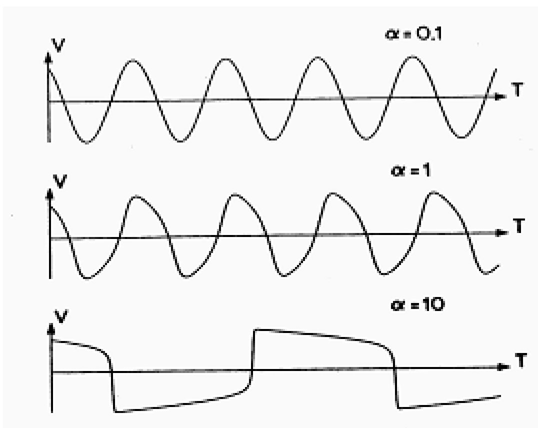
Synchronous Relaxation Oscillators

Lawrence M. Ward

1. Relaxation Oscillators
    1.1 Frequency easily driven, amplitude invariant
    1.2 Van der Pol Oscillator: unforced, damped, nonlinear
    1.3 *v* is voltage (e.g. across a resister), *t* is time, α (damping) and ω (restoring) are constants that determine the behavior of the circuit

$$\frac{d^2v}{dt^2} + \alpha(v^2 - 1)\frac{dv}{dt} + \omega^2 v = 0$$

Van der Pol Oscillator ω =1:



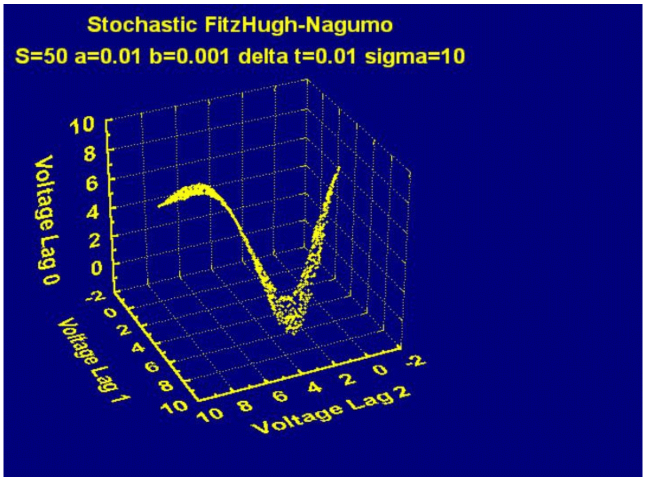
2. Principle 1: Neurons are relaxation oscillators
    2.1 Level 1 oscillators
    2.2 FitzHugh-Nagumo equations as prototype
    2.3 Capture major features of Hodgkin-Huxley and other model neurons

3. FitzHugh-Nagumo Model Neuron Equations
    3.1 Van der Pol oscillator with ω = 1
    3.2 Forcing input *z, v* fast voltage, *w* slow voltage
    3.3 α > 1 damping, *a, b* recovery rate constants

$$\frac{dv}{dt} = \alpha\left(w + v - \frac{v^3}{3} + z\right)$$

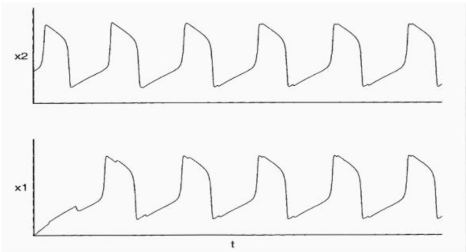
$$\frac{dw}{dt} = -(v - a + bw) / \alpha$$

Chaotic FitzHugh-Nagumo

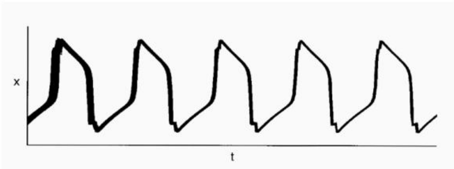


4. Principle 2: Fast Synchronization

Two-coupled

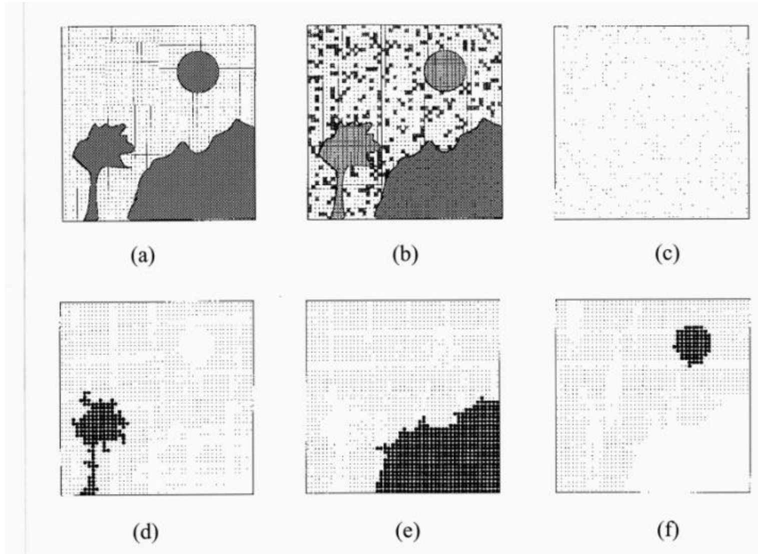


400 coupled



5. Principle 3: Local vs global
    5.1 Local excitatory pulse-coupling leads to rapid synchronization
    5.2 Global inhibitory mechanism can induce rapid de-synchronization
    5.3 Result in automatic segregation of synchronous groups of neurons representing stimuli on the receptors

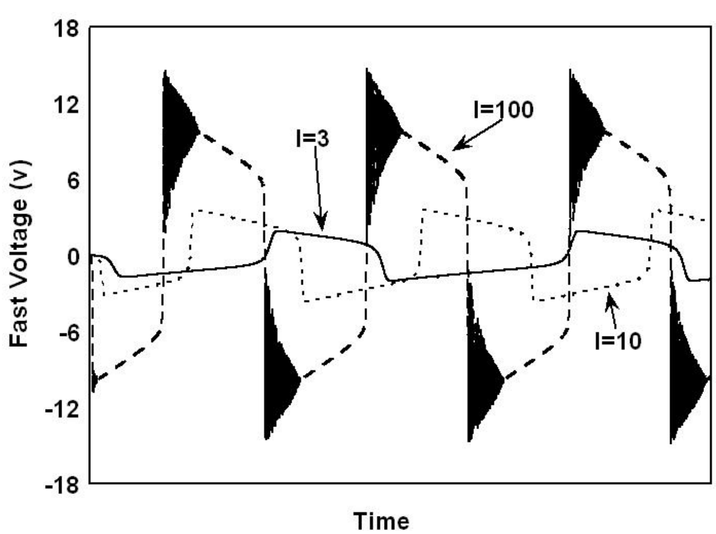
Evolution of Synchrony from a Visual Scene



6. Principle 4: Level 2 Oscillators
    6.1 Formed by groups of synchronously firing Level 1 oscillators (neurons)
    6.2 Modification of the Terman-Wang oscillator is used
    6.3 Sensory representation of a stimulus consists of a Level 2 oscillator

$$\frac{dv}{dt} = Iv - v^3 - w$$

$$\frac{dw}{dt} = \varepsilon\left(8v^3 + 5 - w\right)$$



7. Principle 5: Periodic forcing

7.1 Relaxation oscillators also phase lock to periodic forcing

7.2 I use this as model for interaction of level-2 oscillators

8. Principle 6: Synchrony of relaxation oscillators is ubiquitous; achievable in many ways

9. Principle 7: Dynamic core of consciousness is a Level-3 oscillator composed of synchronously interacting Level-2 oscillators

9.1 Tononi et al binocular rivalry experiment: MEG coherence