Contextual Geometric Structures

Modeling the fundamental components of cultural behavior

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What is the essence of culture?

Heredity (beliefs that propagate)? Plasticity? Self-reference?

Structuralists, post-structuralists: “structures” transcend cultural transmission and cognition, but fundamentally shape that features of culture.

Structures are ubiquitous:
* language and concepts (natural world defined as sets of discrete oppositions).

* settlement patterns, architecture (can define or sharpen distinctions between cultural groups, but can also act to integrate cultural traditions -- syncretism).

* underlying constraints (specifies how cultures CANNOT adapt).
Hybrid (Soft Classification, LCS) Model

Two components of this model:

1) Soft classificatory kernel

* soft classification (all phenomena = degree of membership).

* halfway between light and dark (50% light, 50% dark). Attributes of both.

2) Lagrangian Coherent Structure (LCS) model

* second-order Lagrangian (LCS = recently discovered Physical model).

* hydrodynamic-inspired field model. Currents lead to patterns of movement and aggregation.
Example of Soft Classification

Each object being classified = continuous membership function (0-100%) in each category (n-tuple space).

* categories are not transitive nor independent.

**EXAMPLE:** car crash in a 3-tuple space.

* membership functions: vision (80%), audition (80%), olfaction (10%).

* creates a bounding polygon (all possible responses to sensory stimuli) within which all individual experiences will reside.

In general, subspaces can be defined by culture-specific, context-specific instances.
Soft (fuzzy) classification:

* membership function on interval \( \{0,1\} \). \textbf{NOT} a probability.

* does \textbf{NOT} require transitivity, distributivity, or symmetry
How does the brain “represent” sensory information to perform a cultural “operation”?

* n-tuple surfaces with a soft classification scheme (all possible combinations).

* Cultural phenomenon: symbol, practice, or artifact.

* What is the membership of cultural phenomenon $x$ in this space?

Conceptual Automata

Inspired by the concept of Habitus (Pierre Bourdieu, “Logic of Practice”):

* definitions: “durable, transposable dispositions”….”generative”….”organizes practices and representations adaptively”.

Computational objective: a scheme that transforms physical phenomena into operations that can be compared in an evolutionary context.
Lagrangian Coherent Structures (LCS)

Q: How can we quantify dynamic, emergent structures? Use Lagrangian Coherent Structures (LCS) approach.

* hard to capture higher-level relationships using simple pairwise comparisons or aggregate measurements (curse of dimensionality).

* swarms, herds, colonies, and flocks: all share a common set of principles – self-organized behaviors (weak, strong emergence).

* behaviors, formation of structure occurs in a medium (air, liquid, etc) and so are analogous to or explicitly involve flows (mechanical representation).
**Original Application Domain:**

**Ecology/Evolution:**


May also be used to “embody” culture (and its evolution) in a quasi-geography……

* structures stored on landscapes (context)……
**Lagrangian Coherent Structures (LCS)**

**Key concept for LCS:** finite-time and finite-size Lyapunov exponents (FTLE or FSLE):

* **FTLE** = evolution of collective particle trajectories over time (find distance for given time interval).

* **FSLE** = evolution of collective particle trajectories across space (find time for given set of distances).

LCS field models are a flexible dynamical system:

* Lagrangian representation of kinematics (special case of classical mechanics). Compare with Eulerian, Hamiltonian representations?

Points in a flow have an initial position. The relationship between these points deformed (flow travels apart) over time:

* distance between points quantified using Lyapunov exponent.

* ridges form in flow map over time/space = coherent structures.
Lagrangian Coherent Structures (LCS)

Finite Lyapunov exponent (related to $\gamma$, key parameter in dynamical systems) defined by:

Lyapunov exponent (scalar value)

Movement of particles (advection)

Coordinate system (interpolation)


A matter of diffusion…..

* particles diffuse across a coordinate system at rate $r$.

* if underlying order, particles will aggregate into larger-scale structures.

* stochastic component (diffusion speed), deterministic component (interface between regimes).
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* can be determined in advance (flow jets produce laminar to turbulent regimes).

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Initial condition: environment is seeded with particles (automata), all clustered in same location:

* one seed per population (can simulate multiple populations).
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Over time (integrated temporal divergence), divergence and co-location of particles leads to “structure” formation:

* structures are composed of particles that survive time evolution (conditional features favor certain conditions to emerge).
2-D Cultural Landscape

2-dimensional flow field:

* all dots begin in center of field, diffuse w.r.t. time.

* each dot in figure represent singular automata.

* vortices, ridges, and clusters predicted.

* aggregation due to common soft classification scheme (based on kernel values).
Examples of Contextual Structures

1) 2-tuple without contextual anchor.

| Light | Dark |
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5) 1-tuple with contextual anchor.
Missing Component of Neural Modeling

Existing models of what the brain does:

1) pattern and category recognition (connectionism).

2) intelligence as prediction (HTM Models).

3) emergent representations (development, evolution)

This approach:
Differencing and integration functions related to symbolic behavior (an emergent approach?).

* event-based selective inhibition in memory, attentional circuitry.

* multisensory integration (superadditive) in superior colliculus.
Supplementary Information for Paper

Fluid Models of Evolutionary Dynamics
http://syntheticdaisies.blogspot.com/p/fluid-models-of-evolutionary-dynamics.html

Interesting Workshop Session!!