A Unified Cognitive Model of Visual Filling-In Based on an Emergic Network Architecture

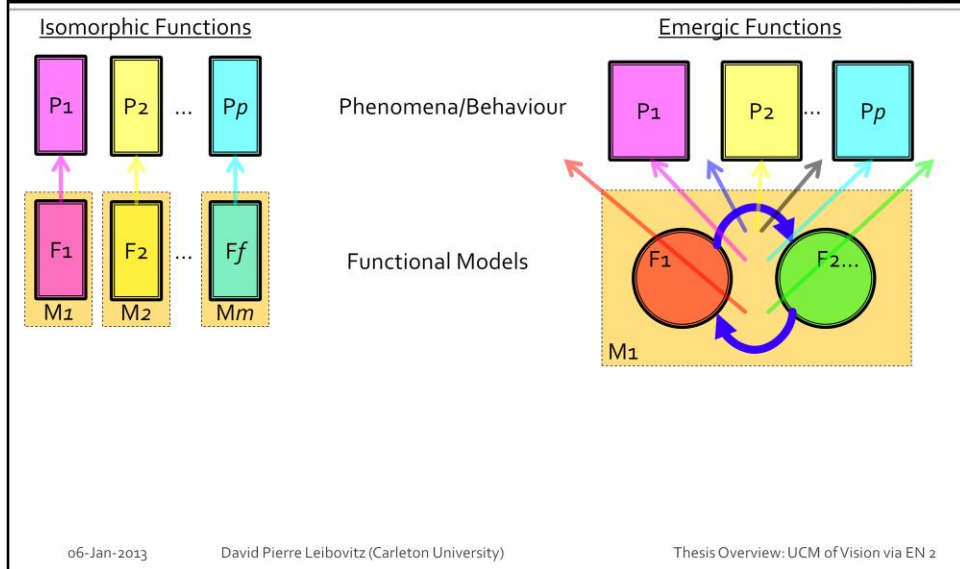06-Jan-2013   David Pierre Leibovitz (Carleton University)   Thesis Overview: UCM of Vision via EN 1

•Presentation look and feel adapted from the "Brain" Microsoft Office Online template.
•Presentation complements the thesis.

- Slide is a caricature to some extent, but…
- Main point is that the resultant decomposition is different and that a new approach is warranted
- Moreover, functional decomposition is multi-realizable. Do we have the right compositions today?

ECM Functional Decomposition

Two parallel & interactive functions:

1. **Maintain Information Coherence**
   - When old information in a recurrent flow meets new information, compensate for motion so that they "refer" to the same "thing"

2. **Handle Missing Data**
   - If bottom-up information is missing, fill it in using lateral or top-down flows
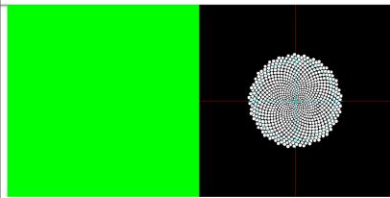   - (This is not an isomorphic "filling-in" process)
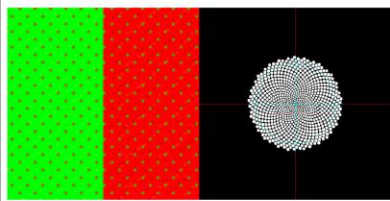
- Parallel, interactive and *non-hierarchical* at this level of analysis
- Not traditional functional formulations
- Descriptive "filling-in" vs. explanative filling-in.

3

Isomorphic vs. Emergic functions
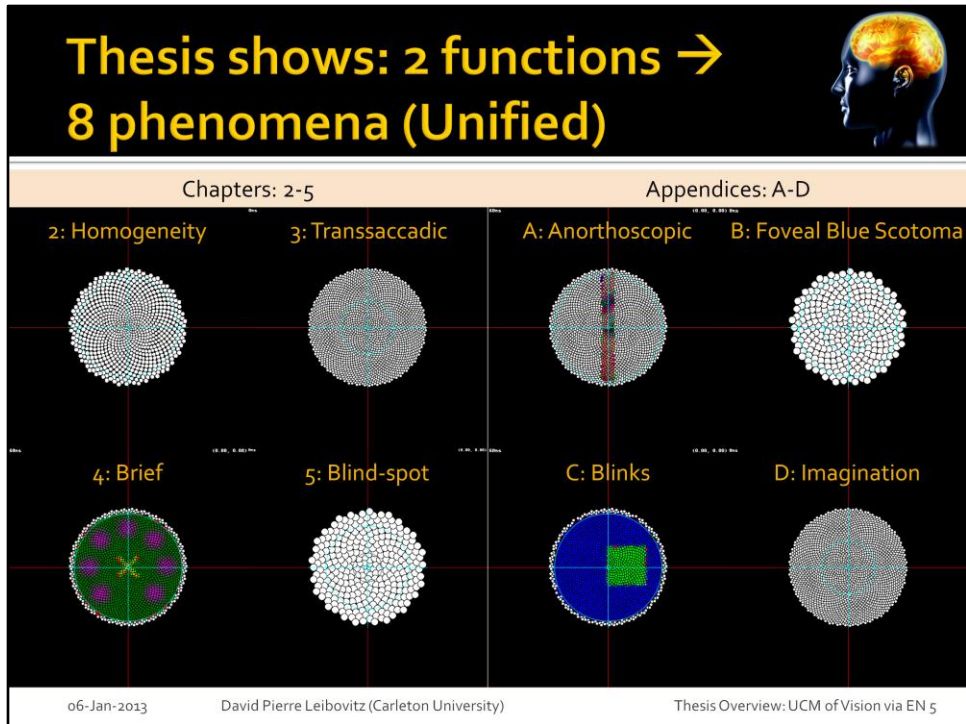
- Emergic filling-in behaviour, but...

- No isomorphic functional filling-in
  - Due to interactions
  - Filling-in over *sensory irregularities* (absences) but not over *stimuli irregularities*

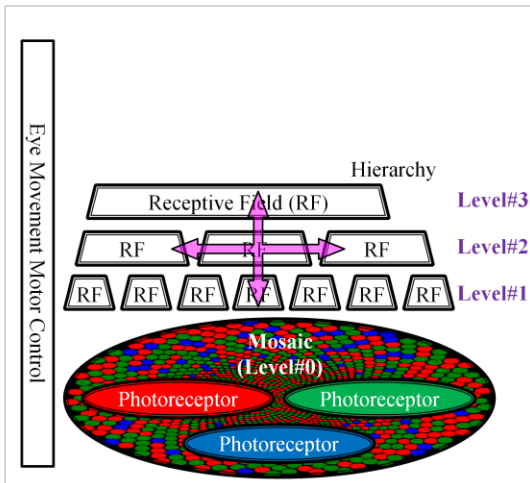06-Jan-2013   David Pierre Leibovitz (Carleton University)   Thesis Overview: UCM of Vision via EN 4

- Functions isomorphic to phenomena, e.g., filling-in function, have trouble when behaviour should not occur
  - They are the wrong functional decompositions
  - Filling-in should remain descriptive and not explanative
- Our explanative functions are finer grained and not explicitly about filling-in
  - Filling-in behaviour emerges when required

4

Thesis shows: 2 functions →
8 phenomena (Unified)

Chapters: 2-5		Appendices: A-D	
2: Homogeneity	3: Transsaccadic	A: Anorthoscopic	B: Foveal Blue Scotoma
4: Brief	5: Blind-spot	C: Blinks	D: Imagination

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- Each of these lines of inquiry are ordinarily researched independently
    - Each has its own rich phenomenology
- Thesis is organized in a *phenomena first* manner so this presentation will not go into those details
    - This presentation is in a *model first* manner, how it differs from classical approaches, and its strengths

5

ECM Structural Overview

- Ecological validity
  - Detailed retina
  - Motion
- Biological plausibility
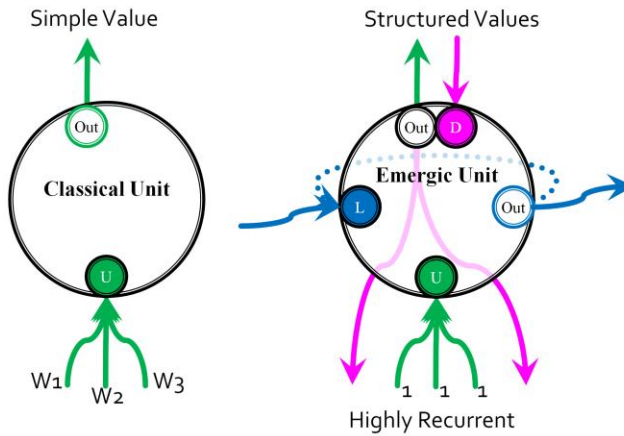 - Multiscale hierarchy
  - Massive Recurrence

Hierarchy

Eye Movement Motor Control

Receptive Field (RF) — Level#3
RF — RF — Level#2
RF RF RF RF RF RF RF — Level#1

Mosaic (Level#0)
Photoreceptor Photoreceptor
Photoreceptor

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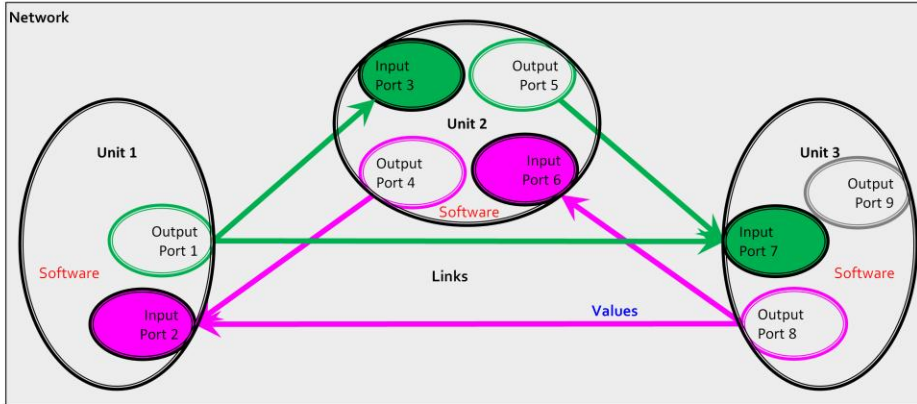
- The building blocks forming ECM

- Each Receptive Field (RF) within ECM is an Emergic Unit
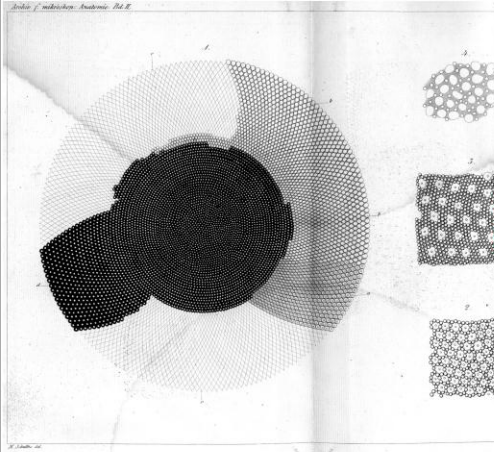
- These are the structural elements forming a prototypical EN
  - Network, Units, Ports, Links
  - Structure of Values
  - Software
  - Ecological situation
- The only dynamics is the flow of values through the network
  - Includes ecological engagement through sensors and effectors

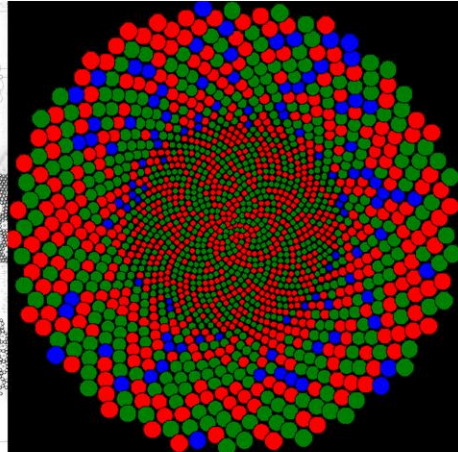Visual Realism: Biological (Photoreceptor Topology)

(Schultze, 1866) | ECM

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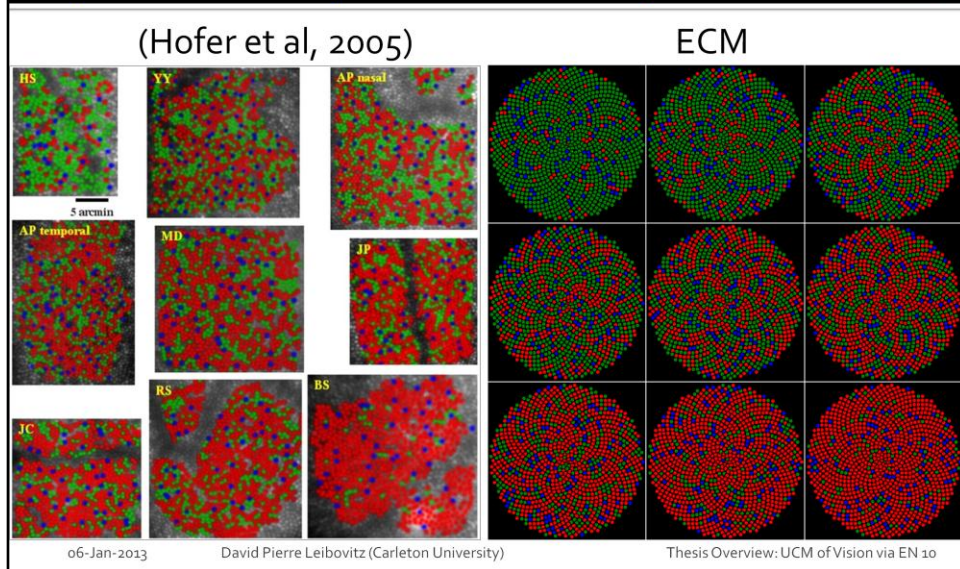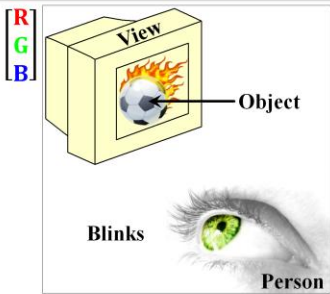
- Blue-free region
- Receptive field sizes that increase with eccentricity
- Random cone sensitivities
- "Random" cone positions

Visual Realism: Biological (Photoreceptor Variance)

(Hofer et al, 2005) — ECM

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- Explain colour homogeneity and linearity

Visual Realism Overview

- Virtual eye "sees" the screen
- Virtual eye jitters
- Virtual eye saccades
- Virtual eye blinks
- Virtual eye has blind spot
- Virtual eye has blue scotoma
- Objects move

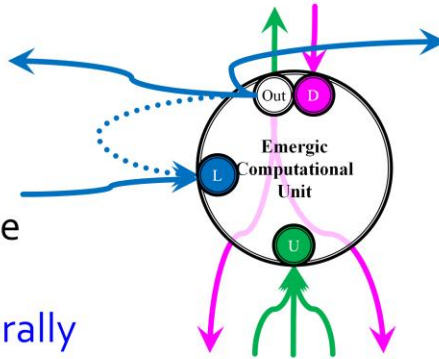06-Jan-2013   David Pierre Leibovitz (Carleton University)   Thesis Overview: UCM of Vision via EN 11

- Non-representational interaction with the environment
- Biological sensory system

Handle Missing Data Function

- This cognitive function is simple
  - If I don't have a bottom-up value, e.g., blinks
    - use lateral value
  - If I still don't have a value,
    - use top-down value
  - Send out my value

- Note: Three flows despite single output as value directed up, down & laterally

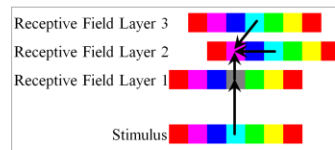06-Jan-2013   David Pierre Leibovitz (Carleton University)   Thesis Overview: UCM of Vision via EN 12

Out   D

Emergic Computational Unit

L

U

- Lateral is "Memory" that can be split/joined by shifting
- Data could be missing due to: heterogeneity; damage; eye blinks; occlusions; beyond the retina; etc.

12

Maintain Information Coherence Function
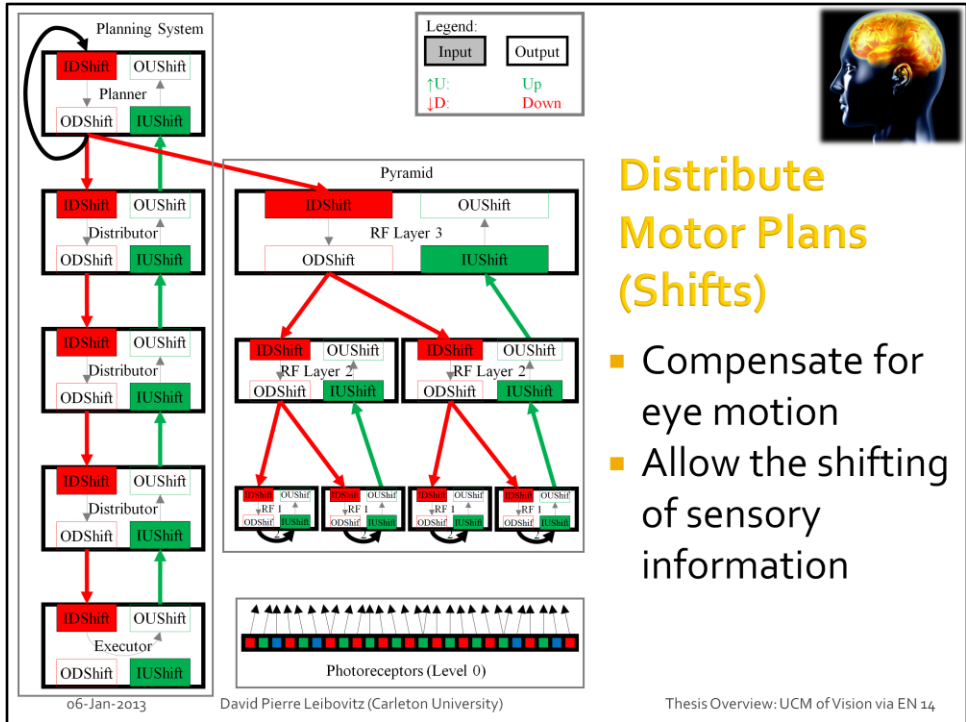
- This cognitive function is complex:
  - Distribute motor plans in advance
  - Shift coordinates to maintain infocentric reference frame
  - Broadcast information locally (~Local Area Network)
  - Tag information (~Internet protocol)
  - Interpolative summation
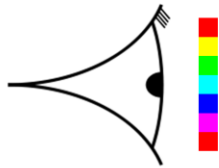
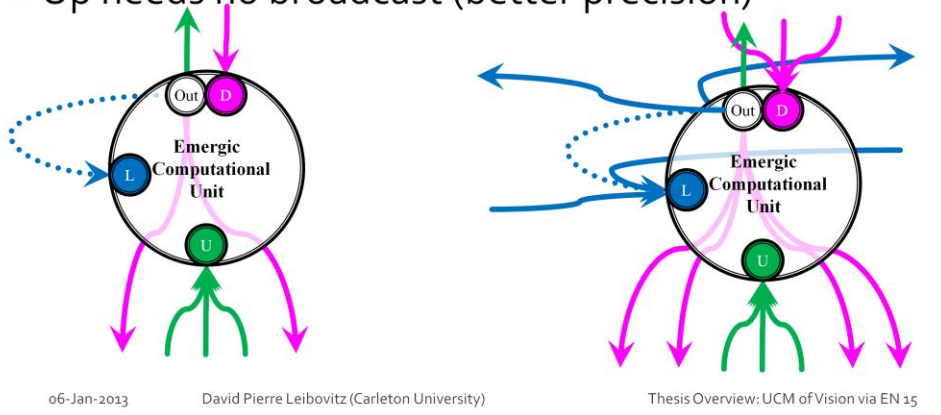|	
Receptive Field Layer 3	
Receptive Field Layer 2	
Receptive Field Layer 1	
Stimulus	

Distribute Motor Plans (Shifts)

- Compensate for eye motion
- Allow the shifting of sensory information

Broadcast Locally

- Like a LAN
  - Cognitive fan-out parameters
- Up needs no broadcast (better precision)

- Lateral is "Memory" that can be split/joined by shifting

Tag Spatial Information in Structured Values

- `ValueXY((x,y,v,w)…)`
  - x: the spatiotopic x-coordinate of this sample value ⎤
  - y: the spatiotopic y-coordinate of this sample value ⎦ —Tag
  - v: the L, M or S colour value of this sample from 0 to 255
  - w: the weight assigned to this sample value
  - …: repeatable, in which case this emergic value represents the descriptive statistics for all the samples weighted accordingly
- Internal Representation (for L, M & S)
  - n: the number of samples = $\sum 1$ $n \mathrel{+}= 1$
  - sw: sum of sample weights = $\sum w_n$ $sw \mathrel{+}= w$
  - swx: weighted sum of X coordinates = $\sum w_n x_n$ $swx \mathrel{+}= wx$
  - swy: weighted sum of Y coordinates = $\sum w_n y_n$ $swy \mathrel{+}= wy$
  - swv: weighted sum of colour values = $\sum w_n v_n$ $swv \mathrel{+}= wv$
  - swxx: weighted sum of X coordinate squared = $\sum w_n x_n^2$ $swxx \mathrel{+}= wxx$
  - swxy: weighted sum of X coordinate multiplied by Y's = $\sum w_n x_n y_n$ $swxy \mathrel{+}= wxy$
  - swyy: weighted sum of Y coordinate squared = $\sum w_n y_n^2$ $swyy \mathrel{+}= wyy$
  - swvv: weighted sum of colour value squared = $\sum w_n v_n^2$ $swvv \mathrel{+}= wvv$
- Mean(x) = swx/sw; variance(x) = (swxx − swx²/sw)/sw; sd(x)=√variance(x)

- Note: the spiking output of neurons alone or in a group does have statistical properties
- The SD is used for calculating spatial overlap between shifting values and static RFs

Interpolation but no Extrapolation
(No Filling-In à la diffusion)

Showing the mean of each RF value ± 1 standard deviation

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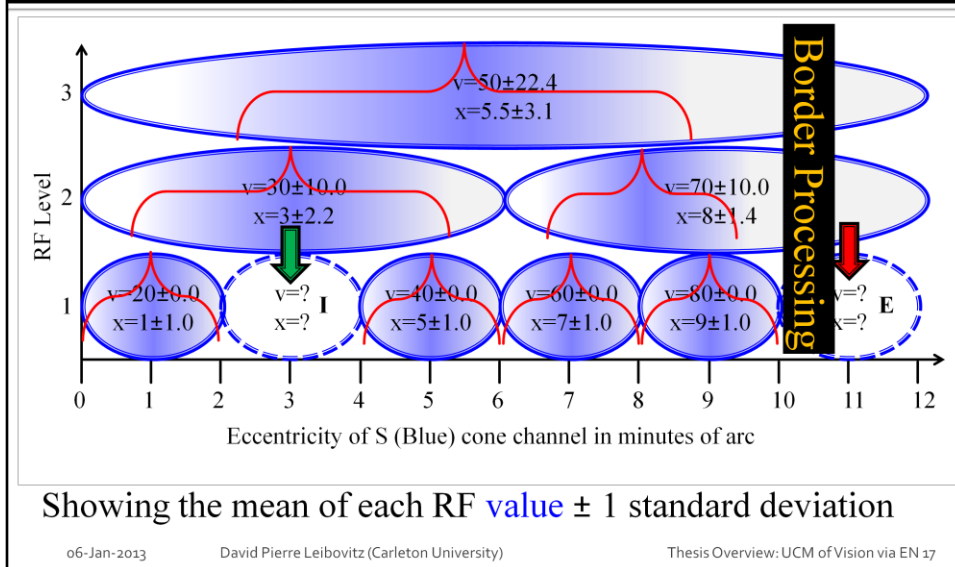
- Gives border/edge processing without specialized neural circuitry

Emergic Cognitive Model (ECM)
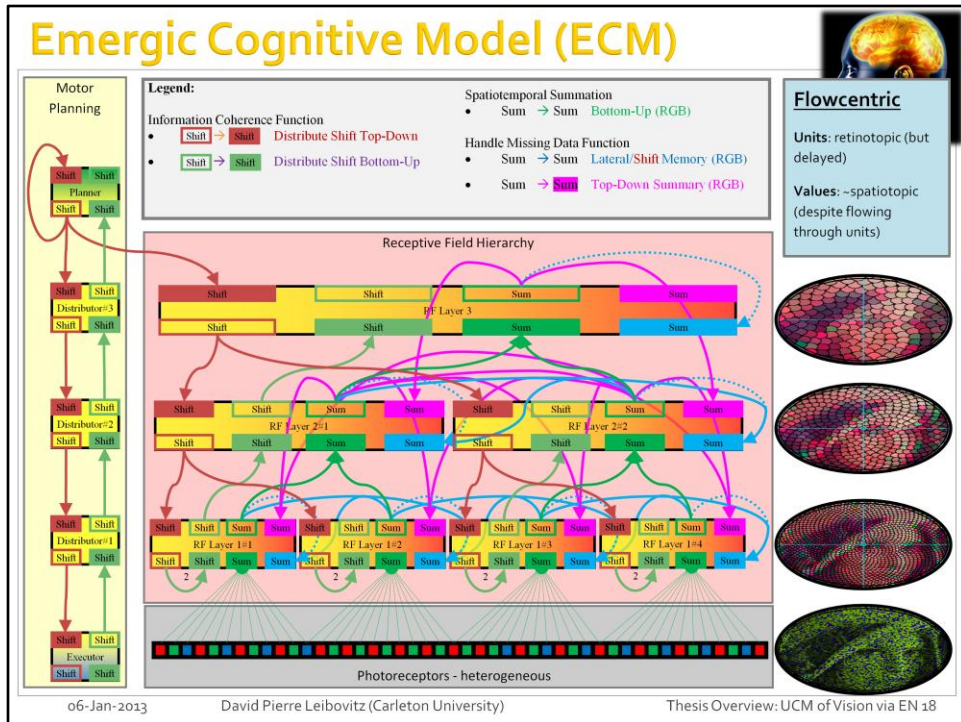
- Each emergic unit has two independent yet interacting parts that lead to emergence
  - Four ports (2 in, 2 out) on the left hand side of each RF for shifting purposes
  - Four ports (3 in, 1 out) on the right hand side of each RF for surface LMS colours (*3)

Image Stability

- Retinotopic
  - Varies with eye motion, E.g., photoreceptors

- Spatiotopic: *neurocentric*
  - Invariant to motion
  - "Paints a stable image onto dedicated neurons"
  - Most commonly sought out, but not found

- Spatiotopic: *flowcentric*
  - Invariant to motion
  - Maintains coherence among moving flows of information
  - Values maintain spatiotopic tags
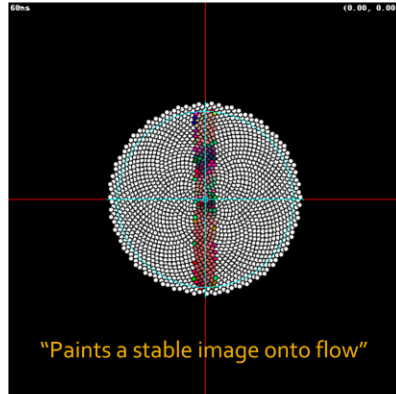
"Paints a stable image onto flow"

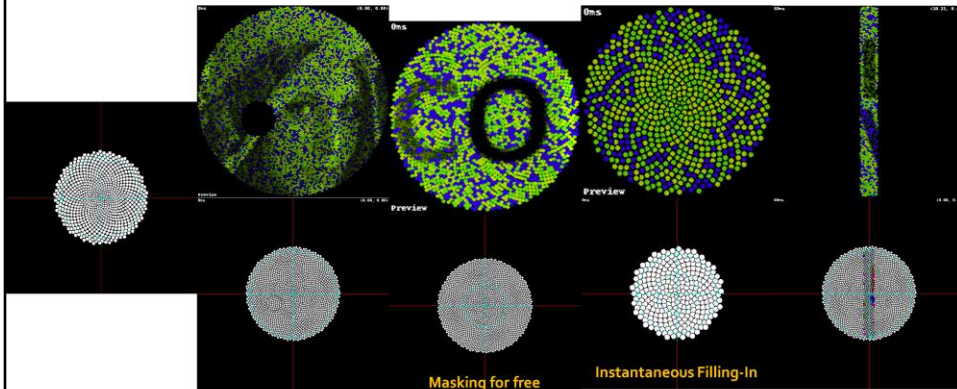06-Jan-2013   David Pierre Leibovitz (Carleton University)   Thesis Overview: UCM of Vision via EN 19

- Possible mechanisms and conceptualizations ought to influence how one measures for image stability.
- Flowcentric suggests an alternative measurement regime and coordinate system
  - Compatible with RF remapping phenomenology
- As all our flows interact coherently, images remain stable within the flow
  - Suggests the *flow* as a locus of consciousness

Handling motion
→emergic filling-in (for free)

- Temporal vs. spatial mechanisms
  - Appears spatial under neurocentric analysis, but
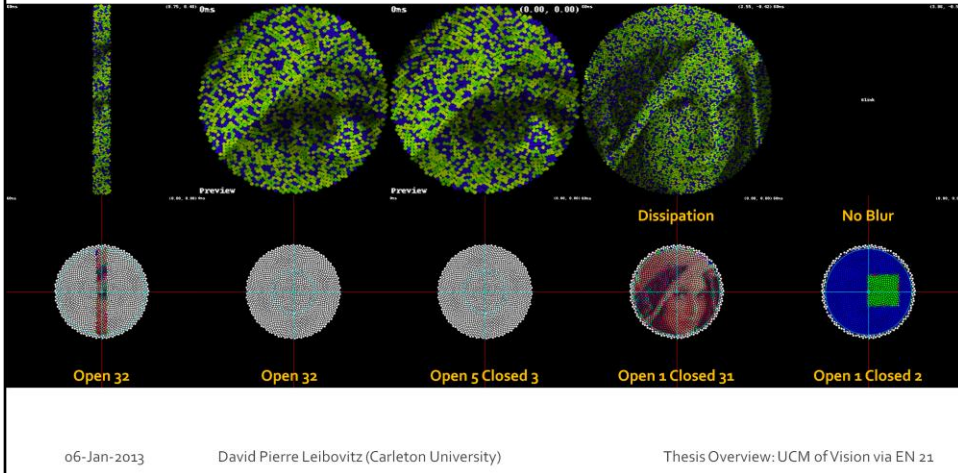 - Actually temporal under flowcentric analysis (cut & paste, e.g., "mpeg vs. jpeg")

Masking for free

Instantaneous Filling-In

CHANGE IS THE ONLY CONSTANT – HERACLITUS

Minimal Blur

Dissipation · No Blur

Open 32 · Open 32 · Open 5 Closed 3 · Open 1 Closed 31 · Open 1 Closed 2

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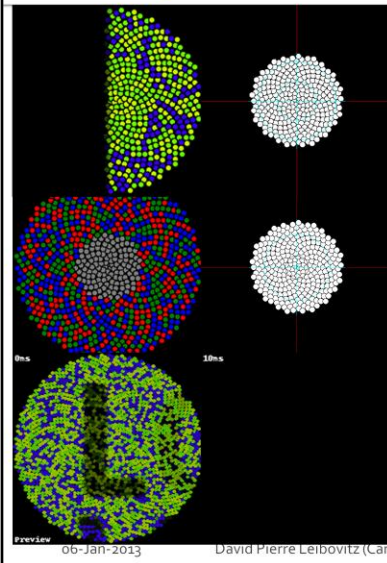
- The entire Emergic Network is synchronous and runs on small time increments called ticks, nominally 10ms each.
  - These are made small enough to simulate an asynchronous dynamic system
- Eyes in third column remain open for 50ms every 80ms.

Border & edge detection and completion

- Most systems have dedicated neural circuitry for border and edge detection and completion
  - Comes for free

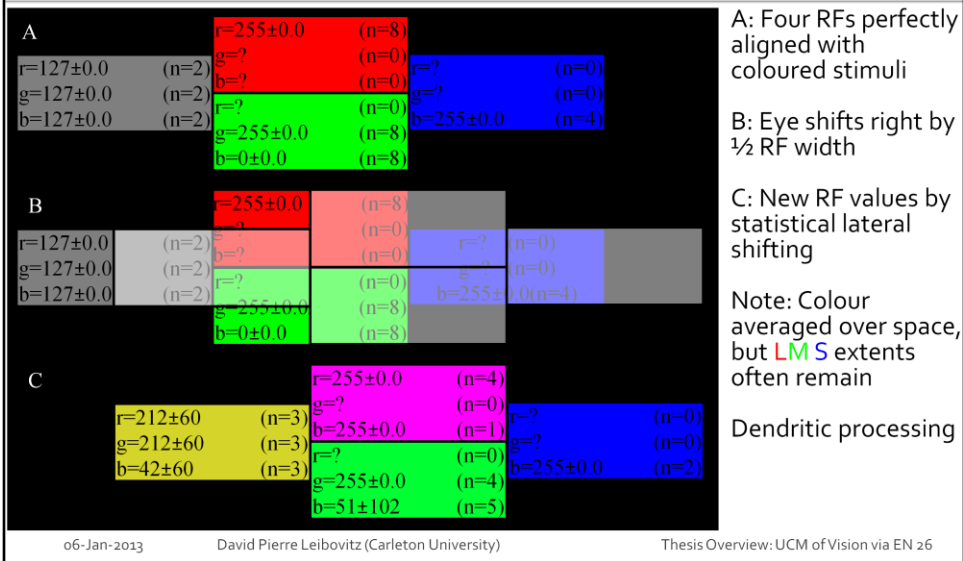- Physical arrangement of RFs less important

- Temporal vs. spatial edge detection

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• Borders are "respected" but not explicitly completed

Future Work

- Connecting model to dendritic processing

- Handling object motion

- Attention

End of Presentation

Backup

Statistical Based Routing/Summing

A	A: Four RFs perfectly aligned with coloured stimuli
B	B: Eye shifts right by ½ RF width
C	C: New RF values by statistical lateral shifting

A:

r=255±0.0 (n=8)
g=? (n=0)
b=? (n=0)
r=? (n=0)
g=255±0.0 (n=8)
b=0±0.0 (n=8)

r=127±0.0 (n=2)
g=127±0.0 (n=2)
b=127±0.0 (n=2)

r=? (n=0)
g=? (n=0)
b=255±0.0 (n=4)

B:

r=255±0.0 (n=8)
g=? (n=0)
b=? (n=0)
r=? (n=0)
g=255±0.0 (n=8)
b=0±0.0 (n=8)

r=127±0.0 (n=2)
g=127±0.0 (n=2)
b=127±0.0 (n=2)

r=? (n=0)
g=? (n=0)
b=255±0.0(n=4)

C:

r=212±60 (n=3)
g=212±60 (n=3)
b=42±60 (n=3)

r=255±0.0 (n=4)
g=? (n=0)
b=255±0.0 (n=1)
r=? (n=0)
g=255±0.0 (n=4)
b=51±102 (n=5)

r=? (n=0)
g=? (n=0)
b=255±0.0 (n=2)

Note: Colour averaged over space, but L M S extents often remain

Dendritic processing

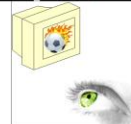06-Jan-2013   David Pierre Leibovitz (Carleton University)   Thesis Overview: UCM of Vision via EN 26

- For top-most RF, ½ Red + ¼ blue overlap → lilac

Modelling Contributions

- Emergic Networks (EN)
  - 1) Model of process metaphysics (EM)
  - Also primary epistemic contribution
  - http://emergic.upwize.com/?page_id=6
- Emergic Cognitive Model (ECM)
  - 2) Detailed model of human retina under motion, blinks, scotomas, etc.
  - 3) Unified model of visual "filling-in" phenomenology
    - Primary ontological contribution
- Emergic Simulation System (ESS)
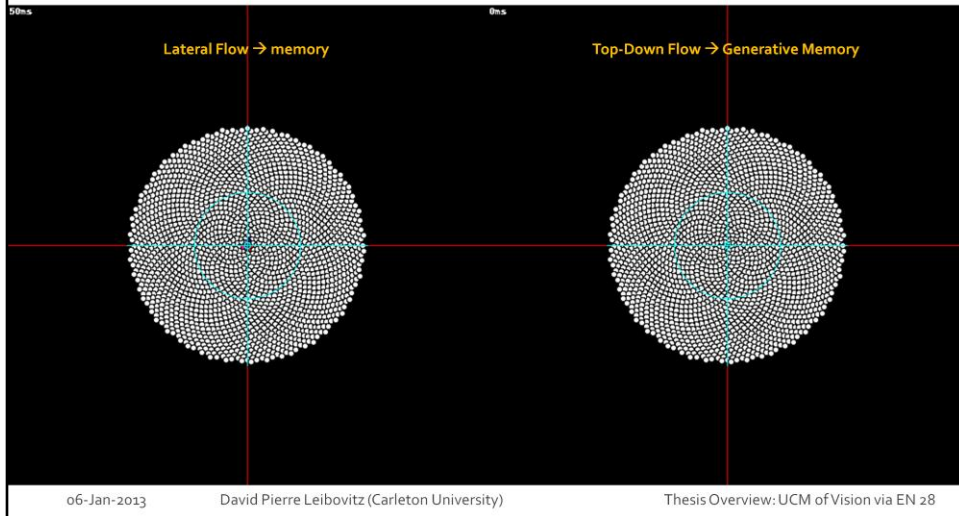 - 4) Model agent/environment interactions
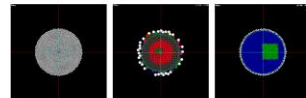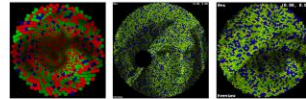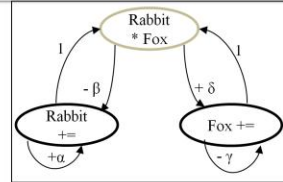
- Top-down is often considered as "merely" modulatory
  - Surprisingly, there are typically more top-down (efferent/feedback) connections than bottom-up
- Memory is normally considered within a neuron, or via interlayer resonance
- All flows are equally important functionally