CAUSAL COGNITIVE ARCHITECTURE 3 (CCA3): A SOLUTION TO THE BINDING PROBLEM

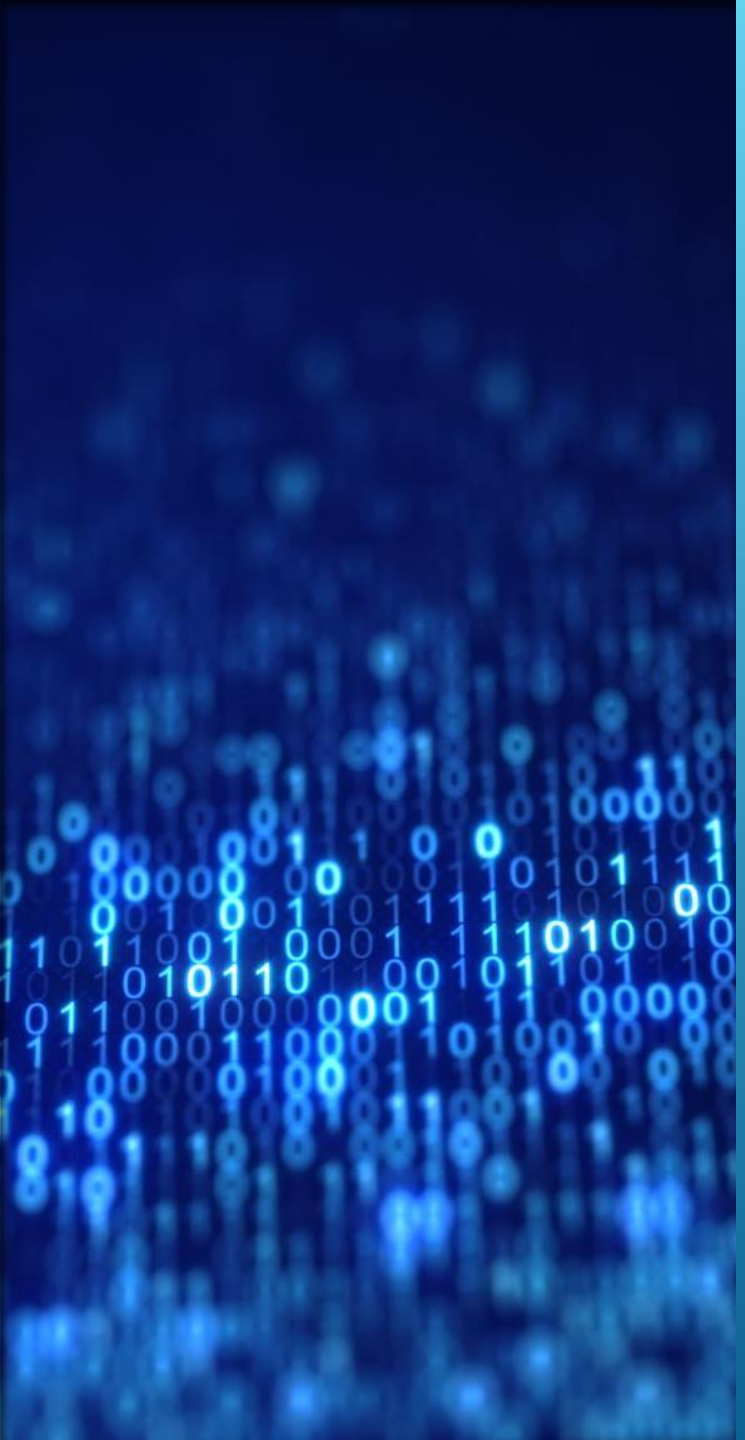
Howard Schneider

Sheppard Clinic North, Ontario, Canada

Cognitive Systems Research, in press
Supplementary Video File

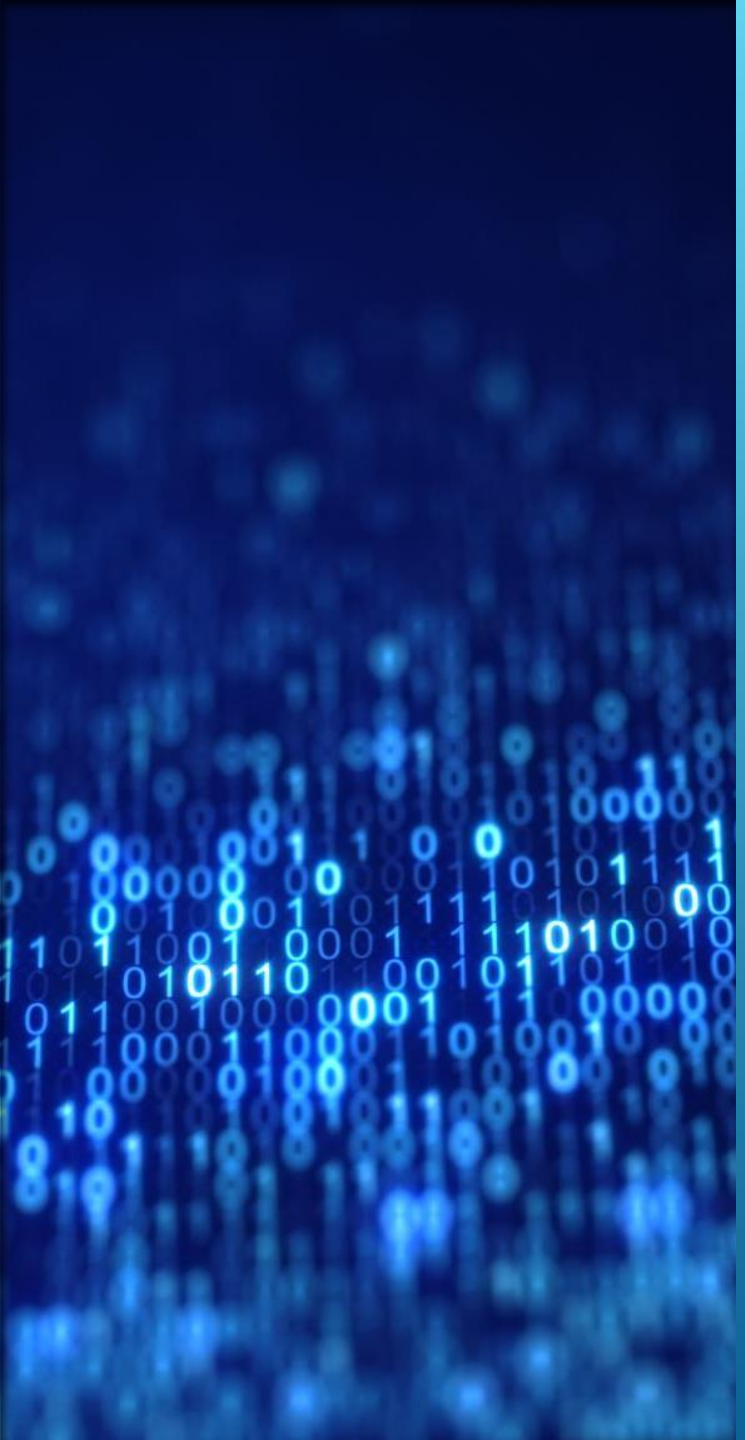
GITHUB Username: "CausalCog"
https://github.com/CausalCog

VIDEO #1



- CCA3 Overview
- Binding Problem Overview
- Software Overview
- Operations Overview
- Operations Causal
- Software in More Detail
- More videos, code on GitHub "CausalCog"

(If interest, continued updating on GitHub)



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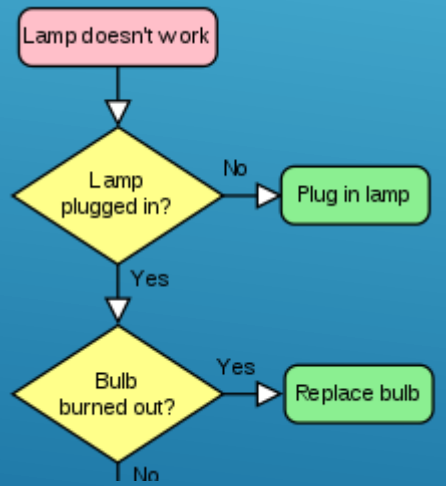
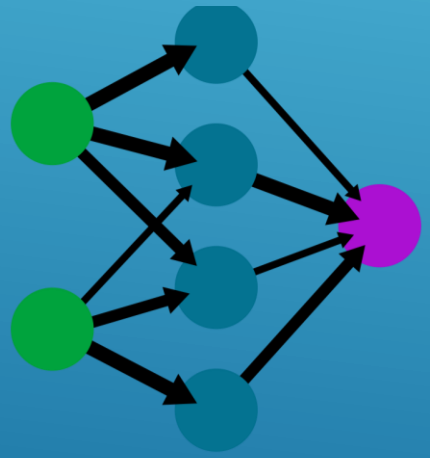
```
self.visual_inputs_zoom_out_assocn_module   ['patient,
self.visual_inputs_zoom_out_motion_modules   []
self.radar_inputs_assocn_module   []

These set of LNM's represent lnm(t) Equation 23
Also, at this time we have effectively extracted motio
as per equation 44  s'_series(t), although not the ful
```

SOFTWARE OPERATION LINKED TO "CCA3 – A SOLUTION TO BINDING PROBLEM" PAPER

What are mechanisms we can use to think…. to make decisions?





Symbolic Logic GOFAI

Neural Networks ANN, SNN

Navigation Maps/ with Causality

symbolic logic, ANN -- wikipedia public domain, mouse, child – unsplash license

Navigation Maps:

Different way of making decisions

Most animals – invertebrates and vertebrates use some sort of navigation system

Navigation Maps:

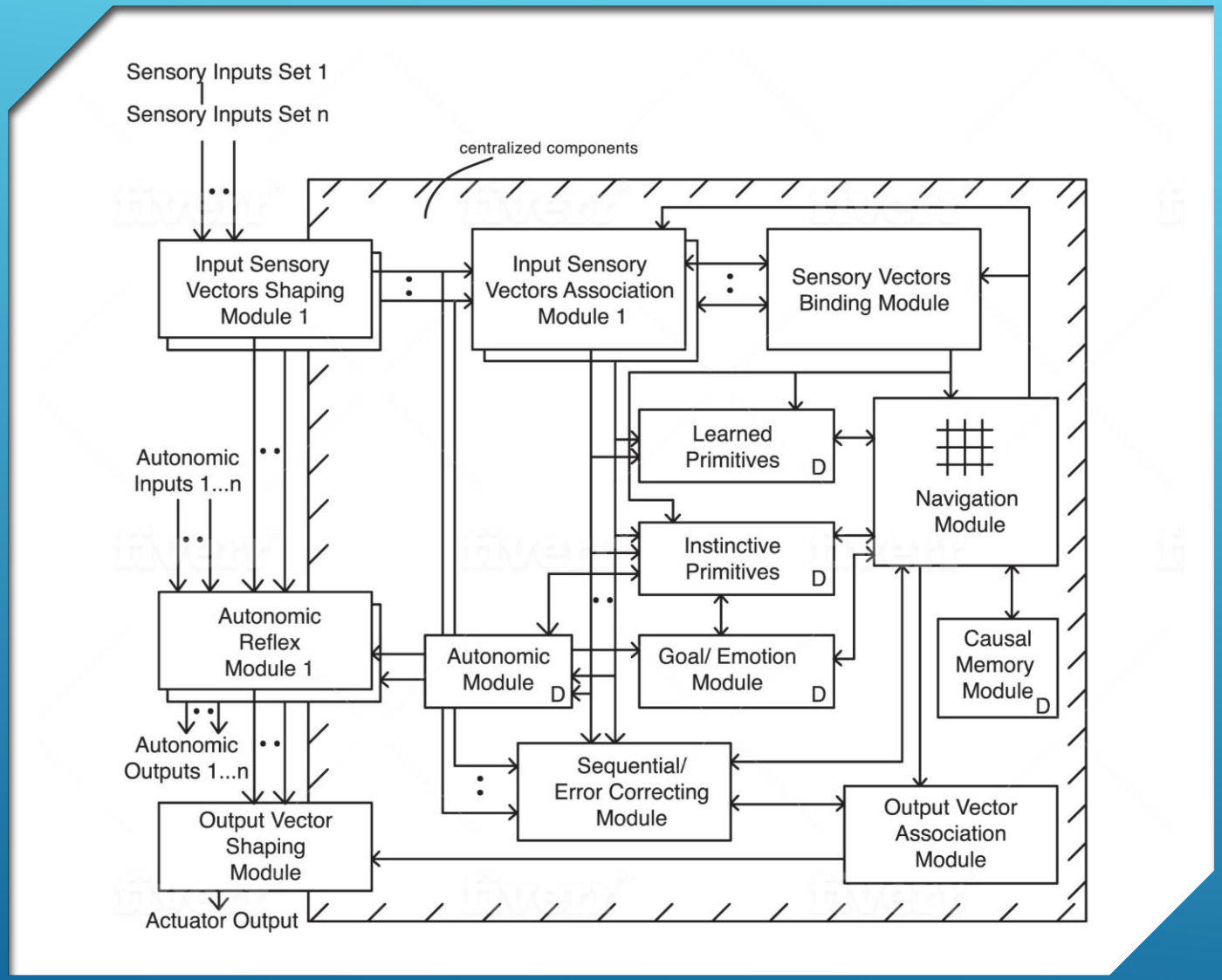
Vertebrates – all have formal navigation systems similar to mammalian hippocampus (place and grid cells)

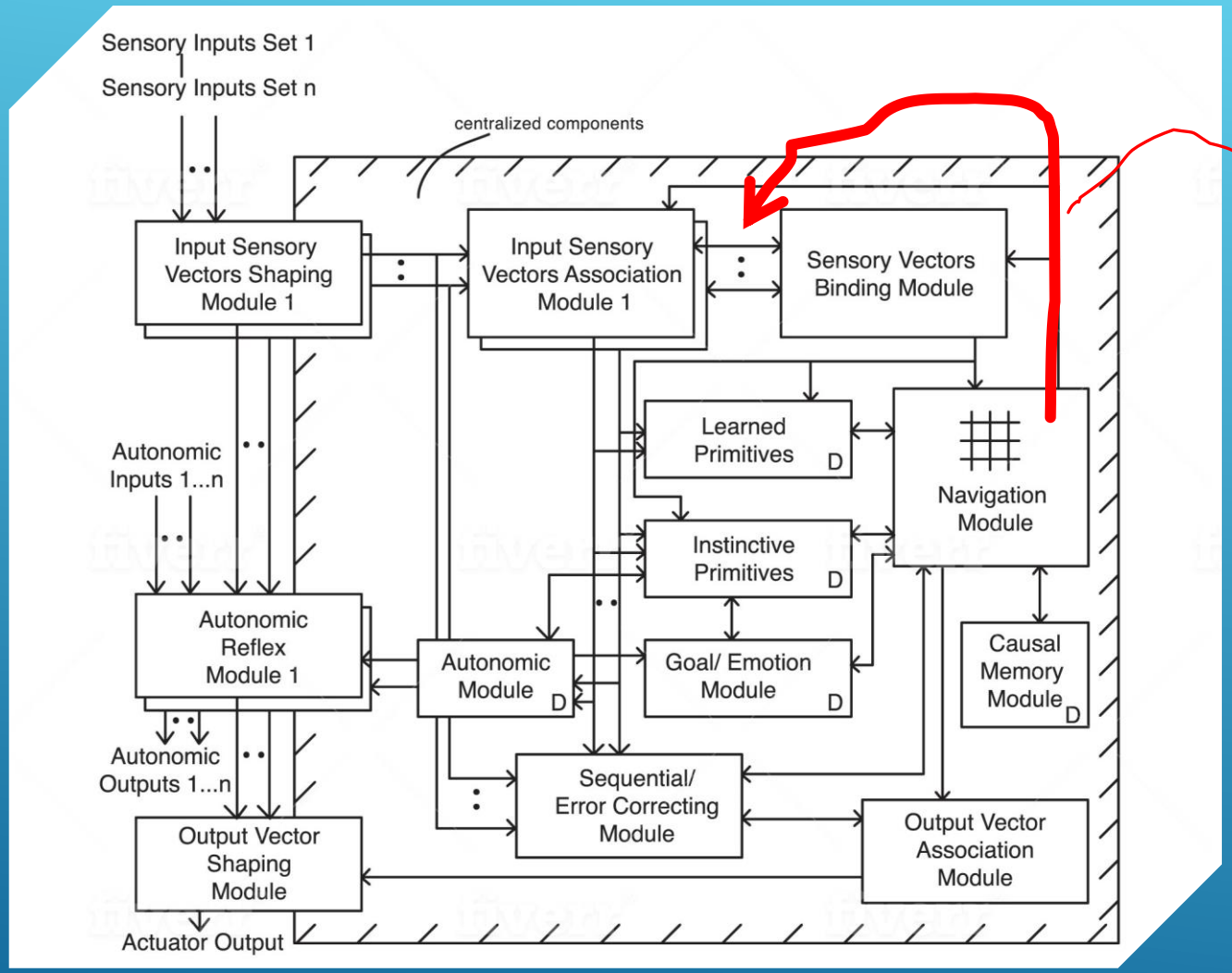
Navigation Maps:

-use in an artificial cognitive architecture not just for navigation but all decisions

→Causal Cognitive Architecture

CAUSAL COGNITIVE ARCHITECTURE 1 (CCA1)
BICA 2018, 2019, 2020





Feedback of partial results, and re-operate on them
→causal behavior
→increase risk psyc

WHY PREVALENCE OF PSYCHOSIS IN HUMANS?

17% some other psychosis or psychosis-like (van Os et al 2001)
(albeit, 1% schizophrenia)

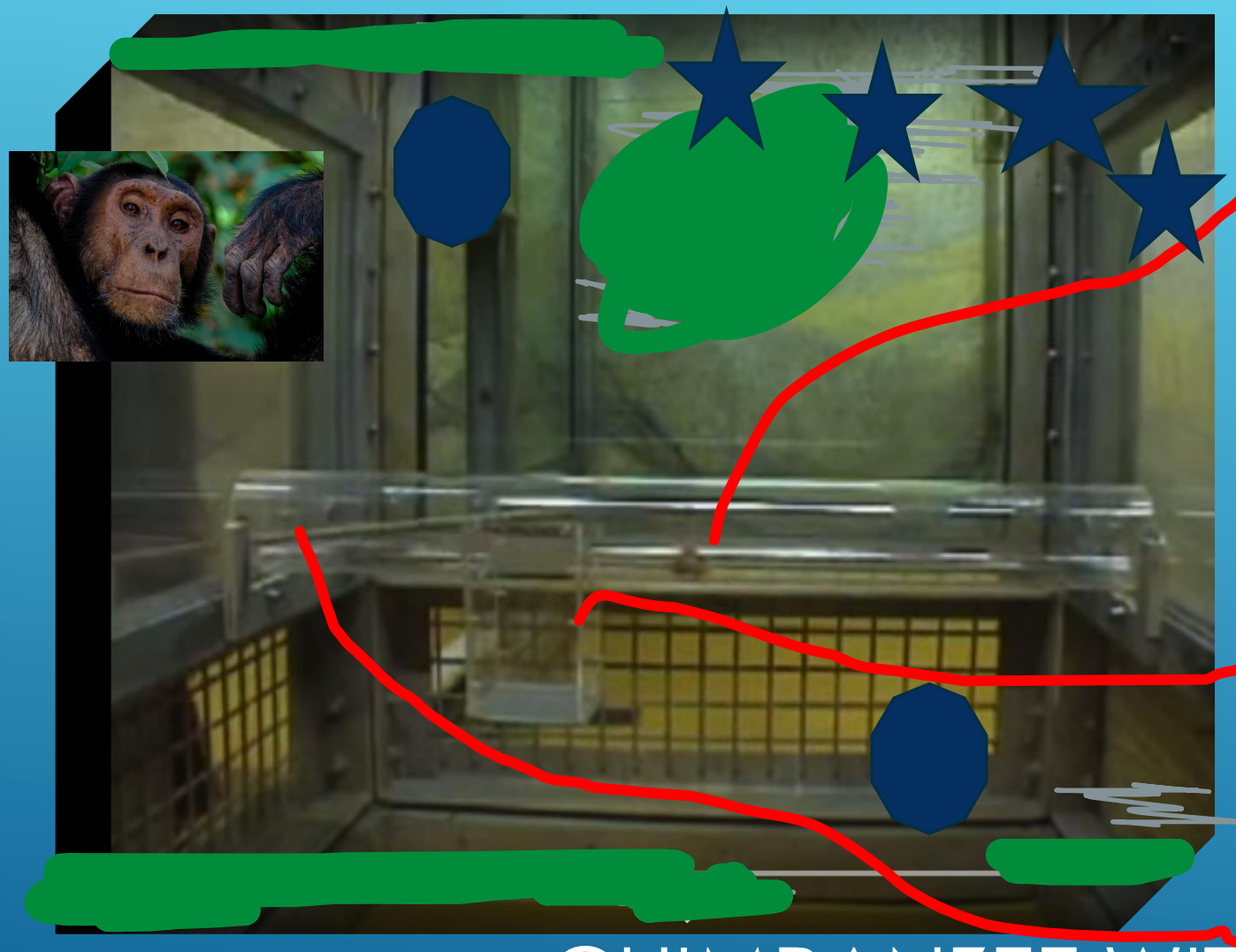
image woman – unsplash license

WHY NO PSYCHOSIS IN ANIMALS?

animal – unsplash license

WHY NO FULL CAUSAL BEHAVIOR IN ANIMALS?

animal – unsplash license



FOOD IN PLEXIGLASS TUBE

GRAVITY TRAP

CHIMPANZEE WITH STICK

youtube image modified by author plus unsplash license chimpanzee face

frontiers in Psychology

ORIGINAL RESEARCH
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2020

Check for updates

Inferring Unseen Causes: Developmental and Evolutionary Origins

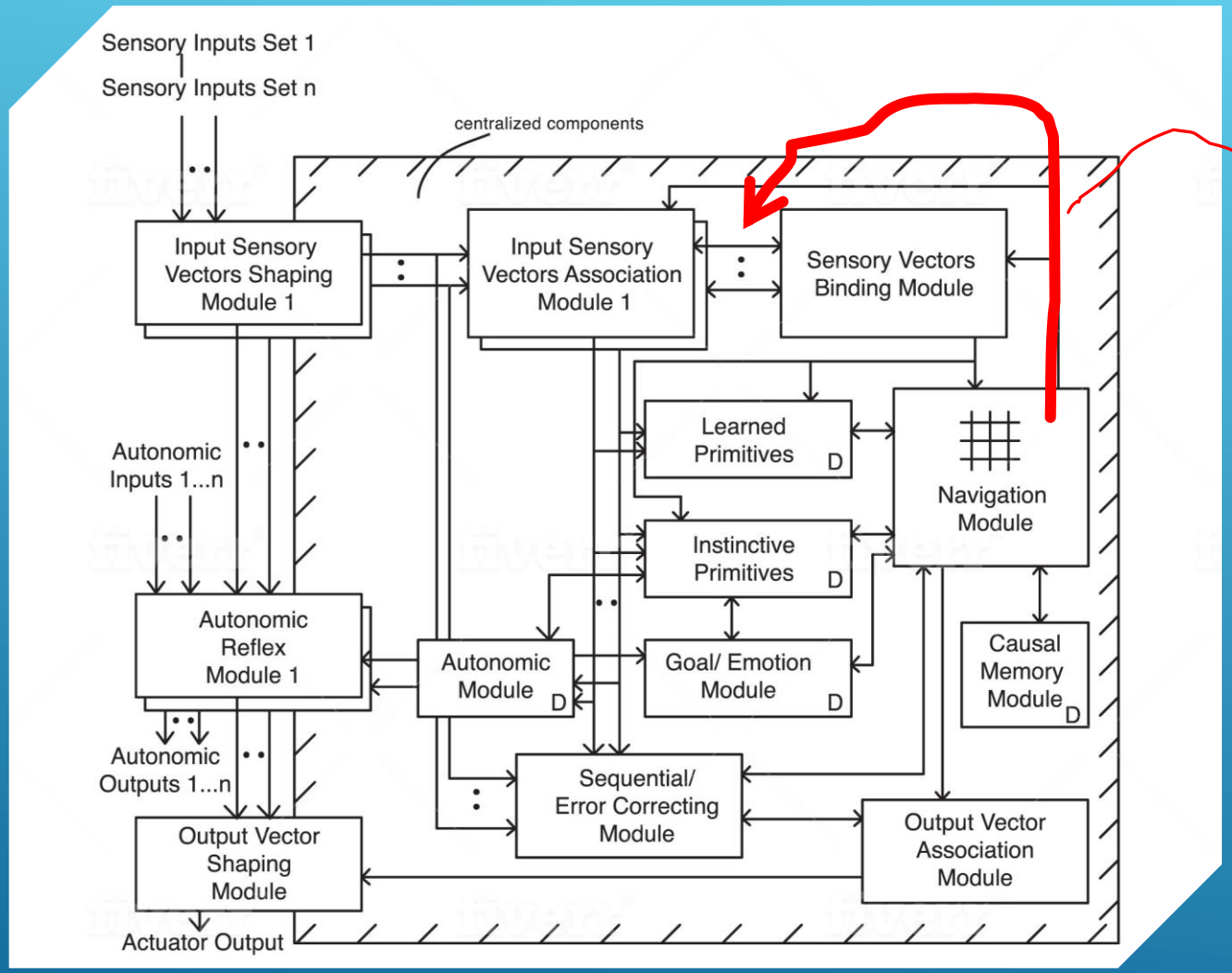
Zeynep Civelek, Josep Call and Amanda M. Seed*

School of Psychology and Neuroscience, University of St Andrews, St Andrews, United Kingdom

reward via opaque tube into cup A or cup B + causal auditory cue

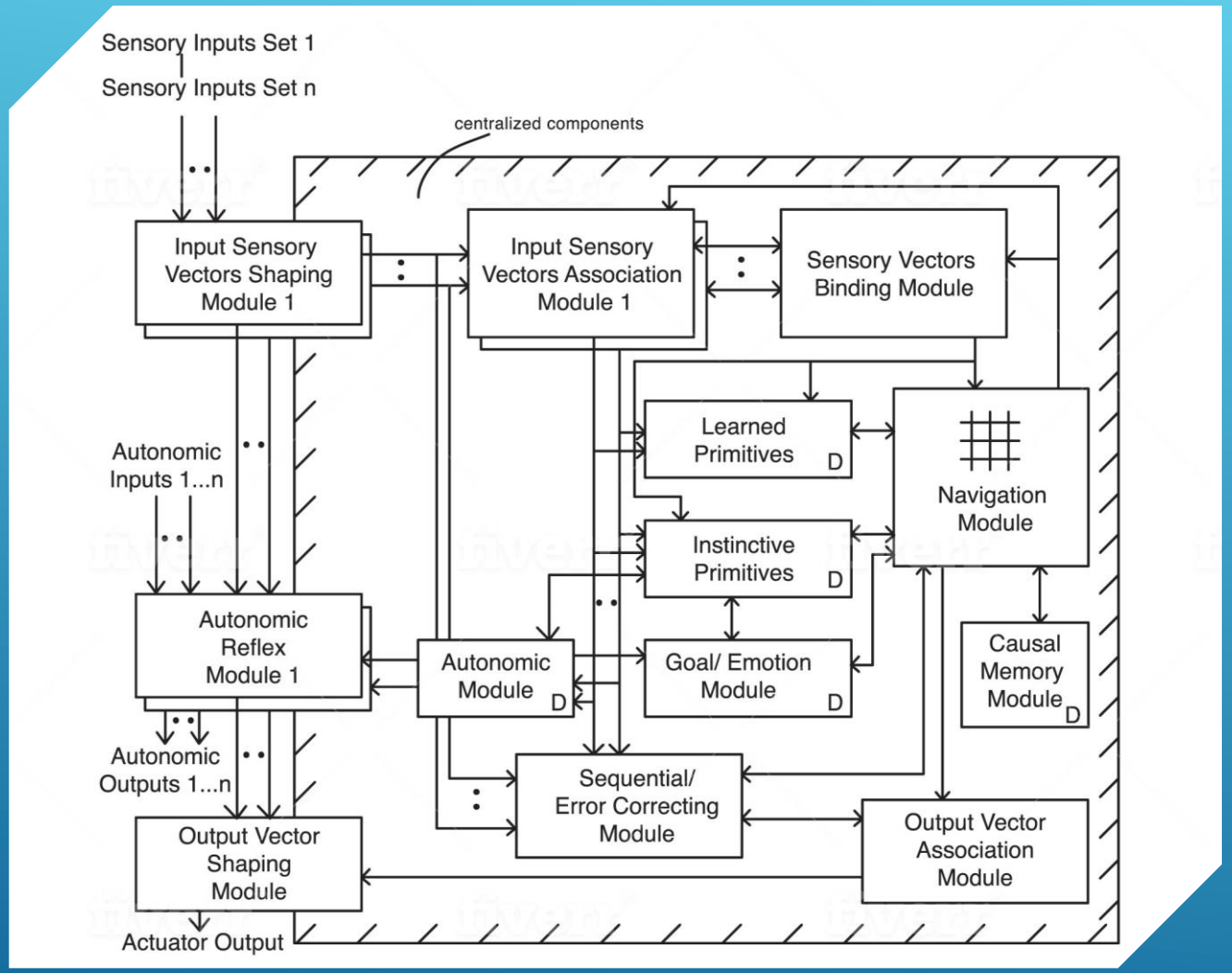
chimpanzee n=11, age 7-41 years old -- performance at **chance**
human child, n= 32, age **3 years** old – performance at **chance**
human child, n= 97, age **4-6 years** old – **causal** performance

child – unsplash license, animal – Wikipedia public domain



Feedback of partial results, and re-operate on them →causal behavior →increase risk psychosis

CAUSAL COGNITIVE ARCHITECTURE 1 (CCA1)
BICA 2018, 2019, 2020



Works for toy problems

CCA1 handles toy problems

Want a more robust version of CCA1

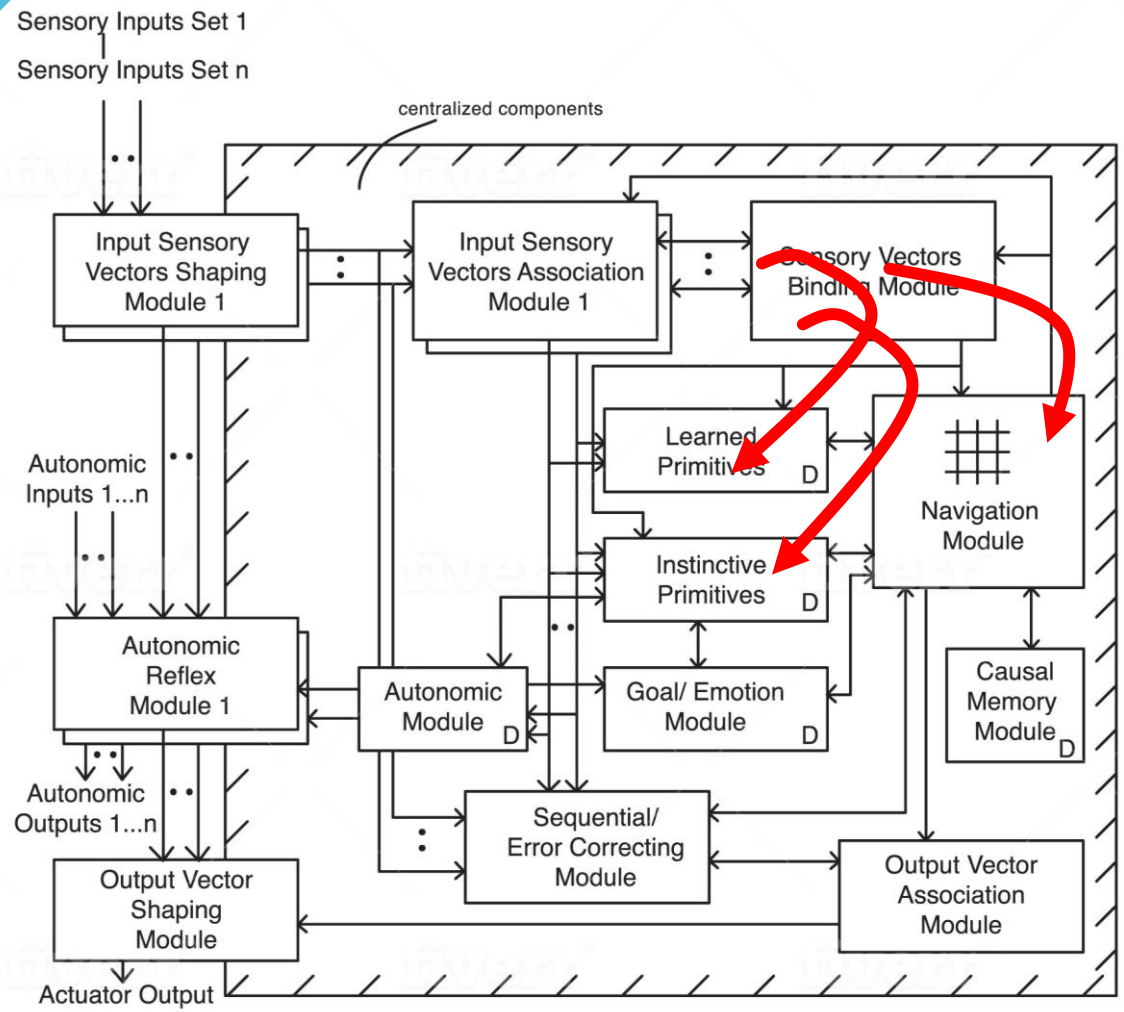
but….problems arising in attempts to enhance the CCA1….

Problem is that Sensory Vectors Binding Module must output some vector which represents object/environment it has detected by fusing sensory features together

How to label different combinations?

Need a binding language of sorts?

Do we need a "binding language" ?



["river", "water"] → river, water

Or maybe: water, river

["river", "water", "object", "bubbling", "algae", "floating", "lines", "turn right", "turn left", "straight"]

→ ?? 10! = 3 million possible steps ??

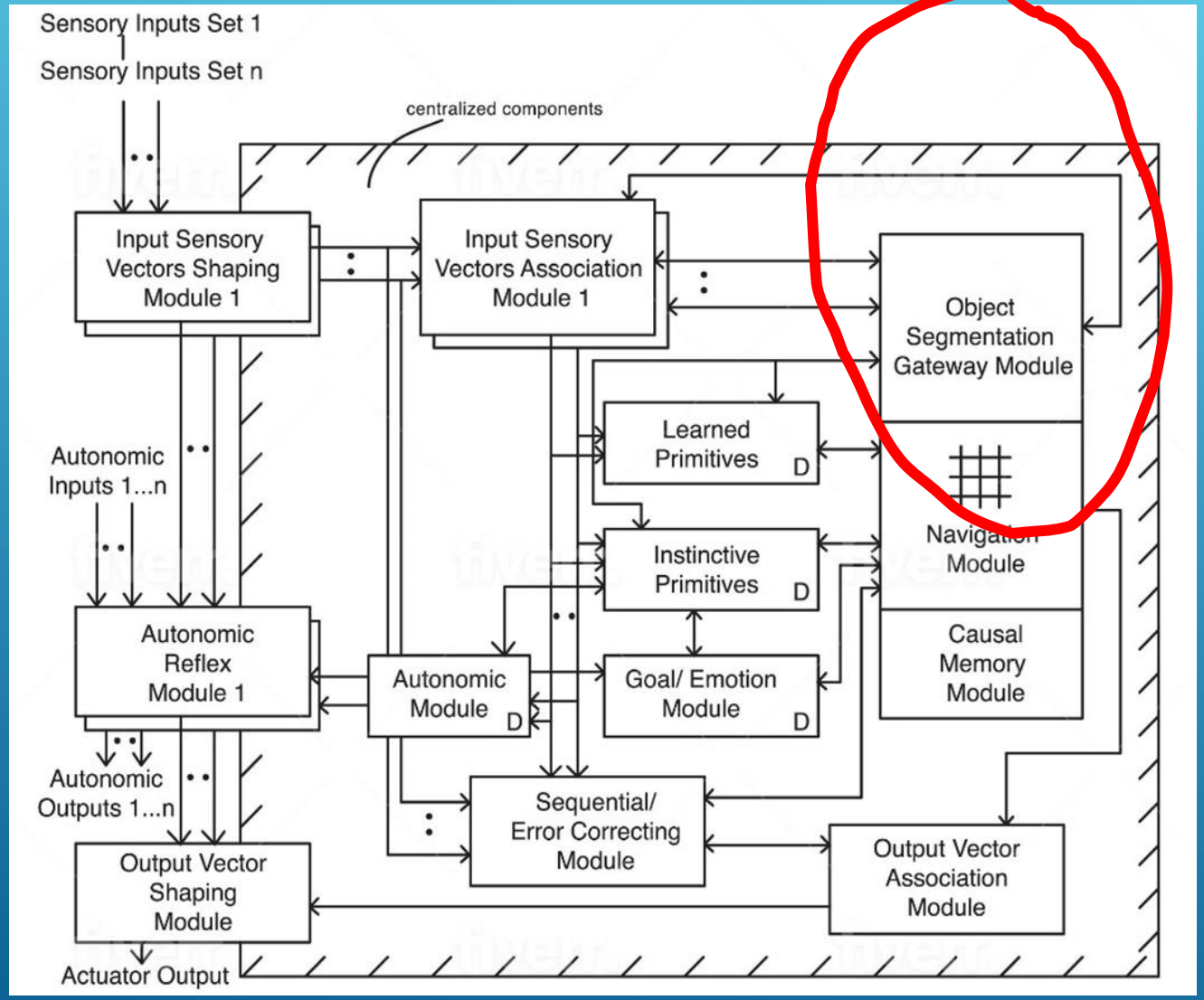
TO HANDLE REAL WORLD PROBLEMS, THE BINDING ISSUE NEEDS TO BE ADDRESSED

The Binding Problem (Feldman, 2013):

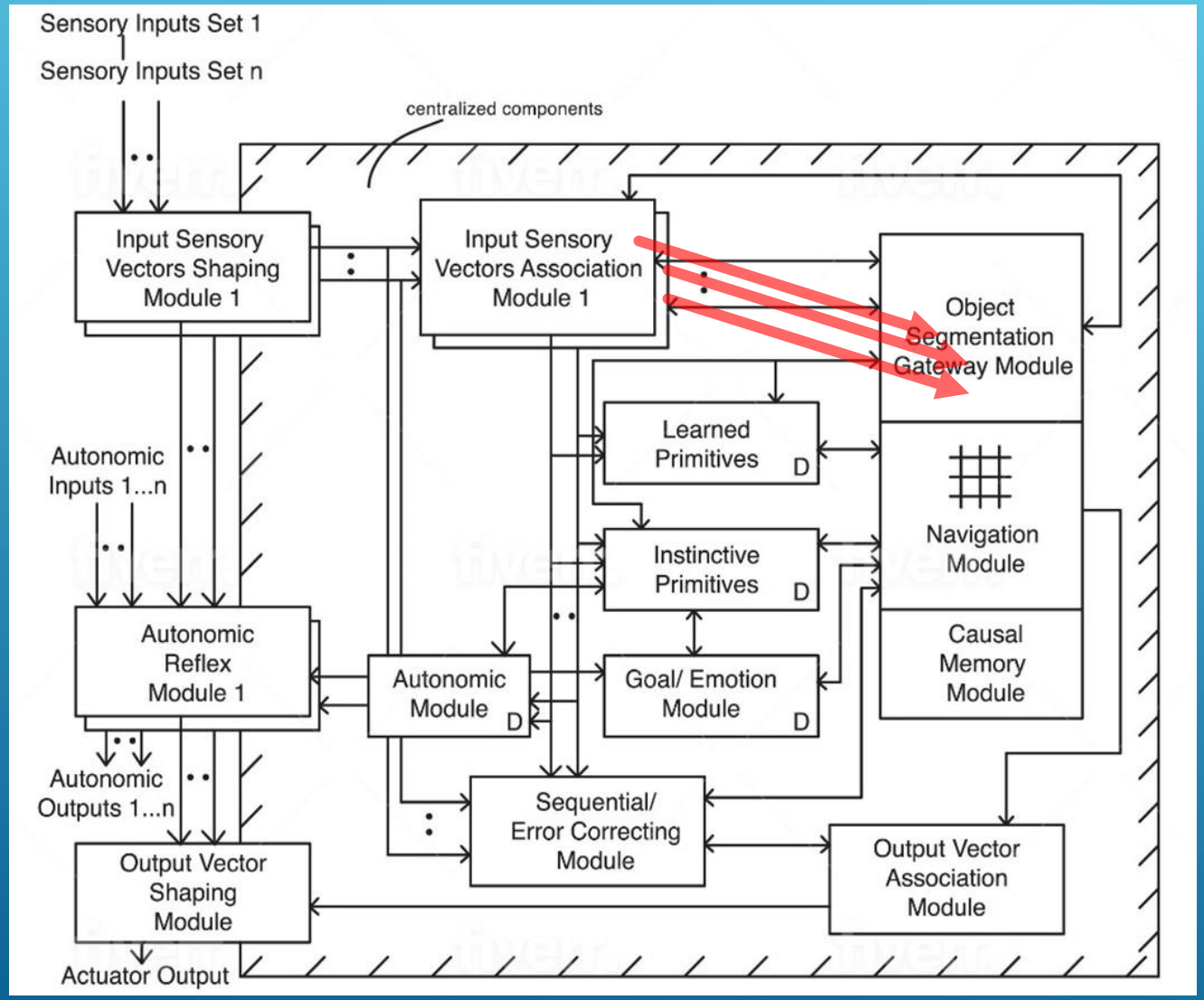
- General coordination of objects and activities
- The subjective unity of perception
- Visual Feature-Binding
- Variable Binding such as the binding of words in a sentence that allow reasoning

CCA2

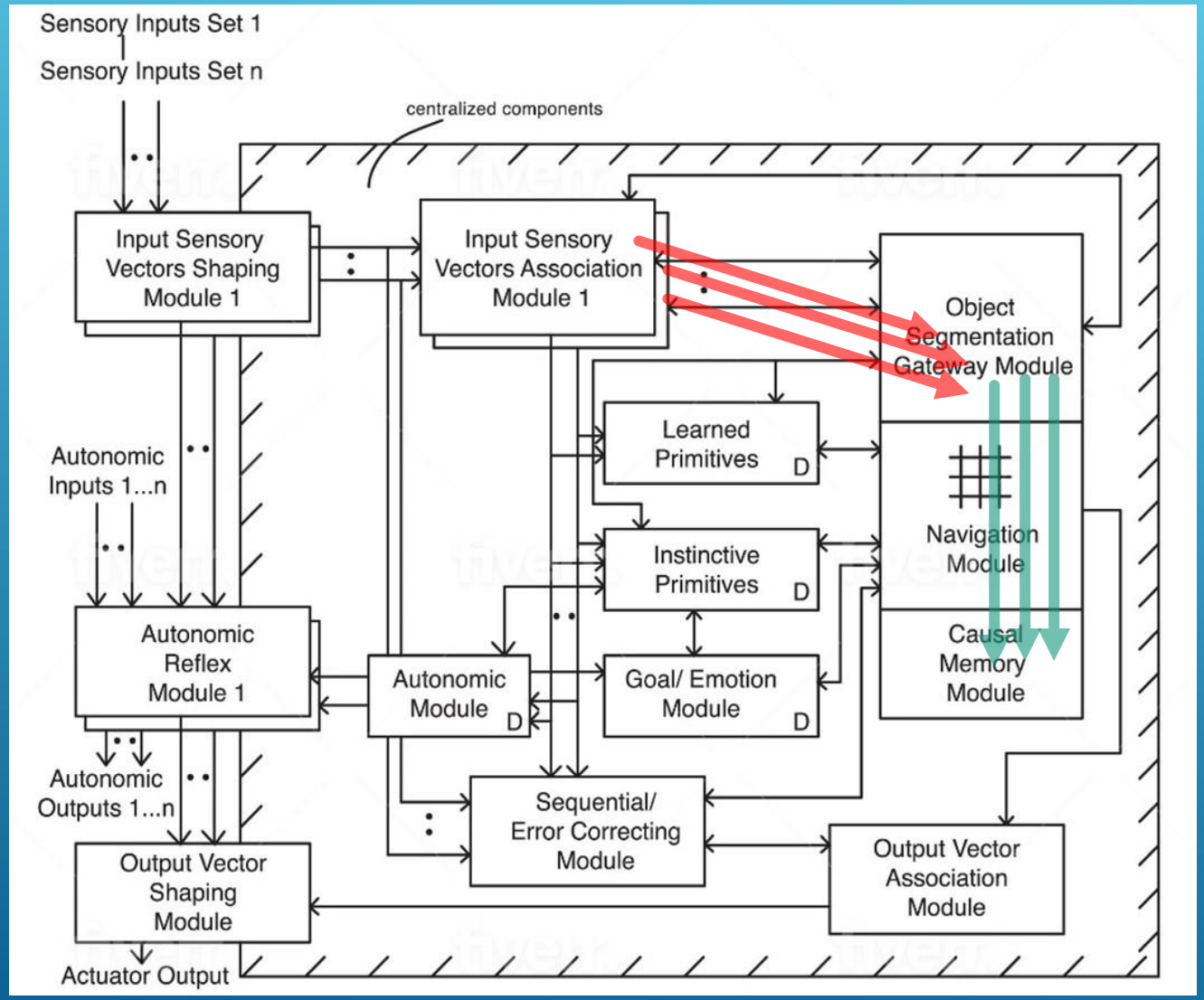
To handle real world problems, the binding issue needs to be addressed



← CCA2


Sensory Inputs Set 1
Sensory Inputs Set n
centralized components
Input Sensory Vectors Shaping Module 1
Input Sensory Vectors Association Module 1
Object Segmentation Gateway Module
Learned Primitives
D
Autonomic Inputs 1...n
Instinctive Primitives
D
Navigation Module
Causal Memory Module
Autonomic Reflex Module 1
Autonomic Module
D
Goal/ Emotion Module
D
Autonomic Outputs 1...n
Sequential/ Error Correcting Module
Output Vector Shaping Module
Output Vector Association Module
Actuator Output

← CCA2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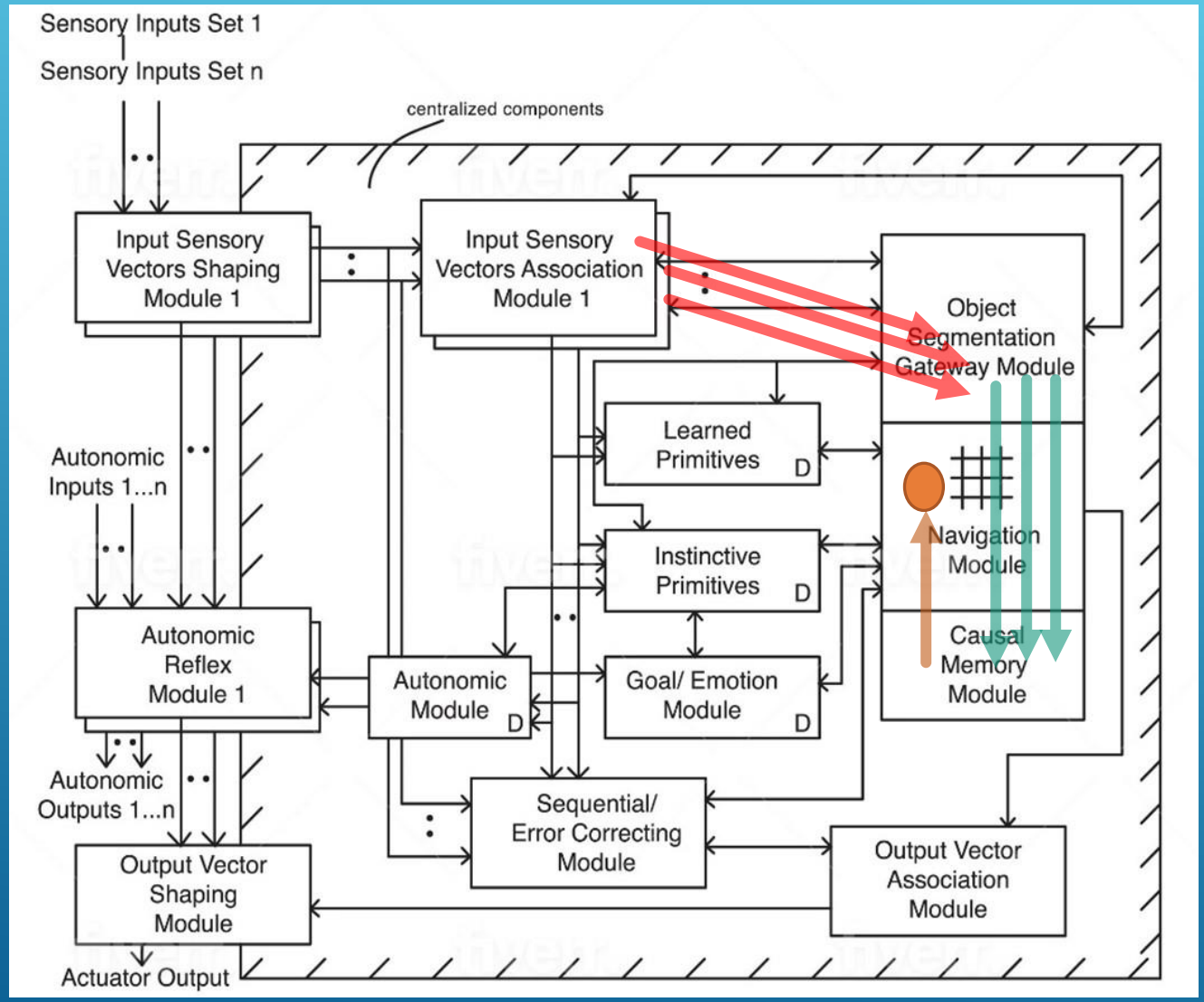
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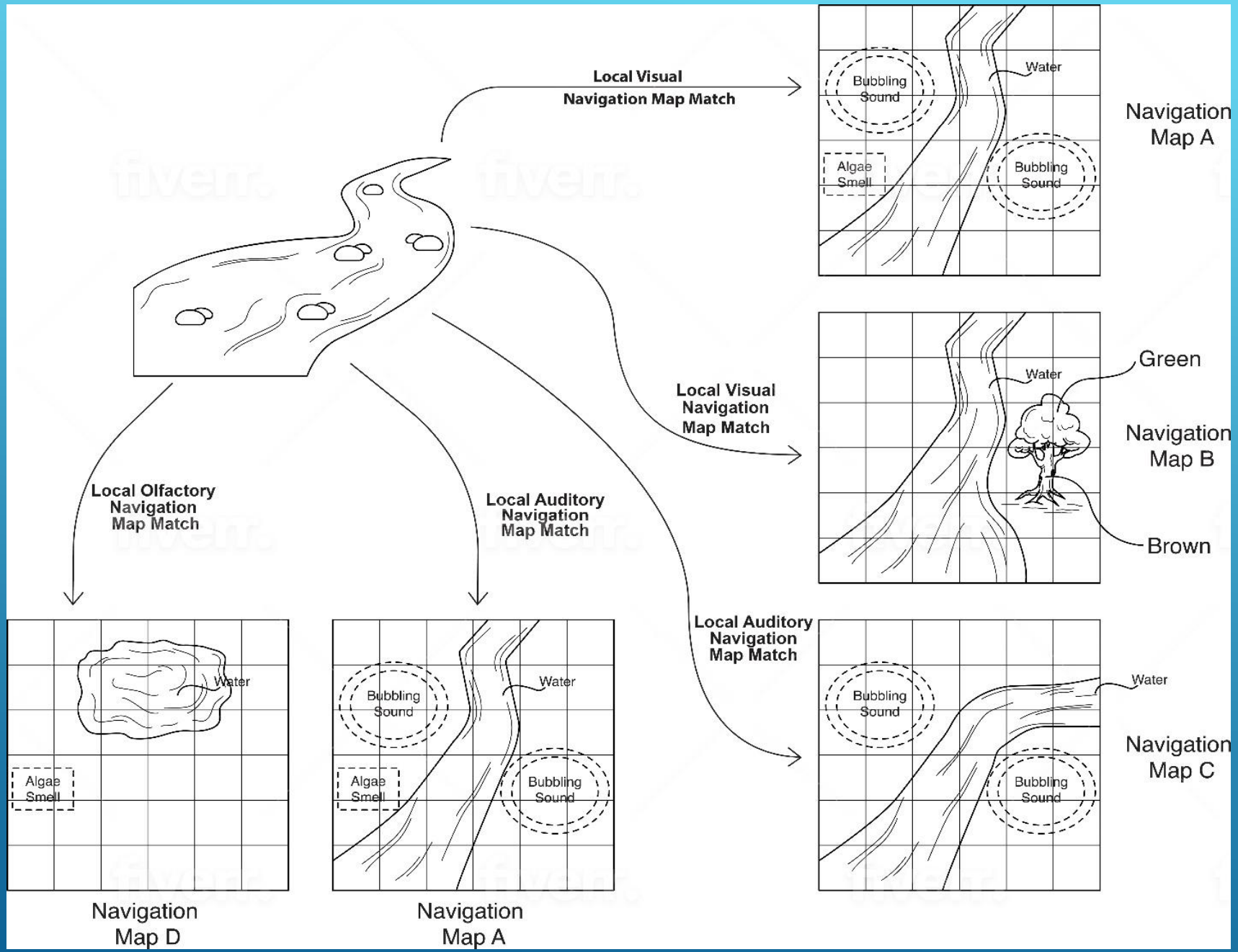
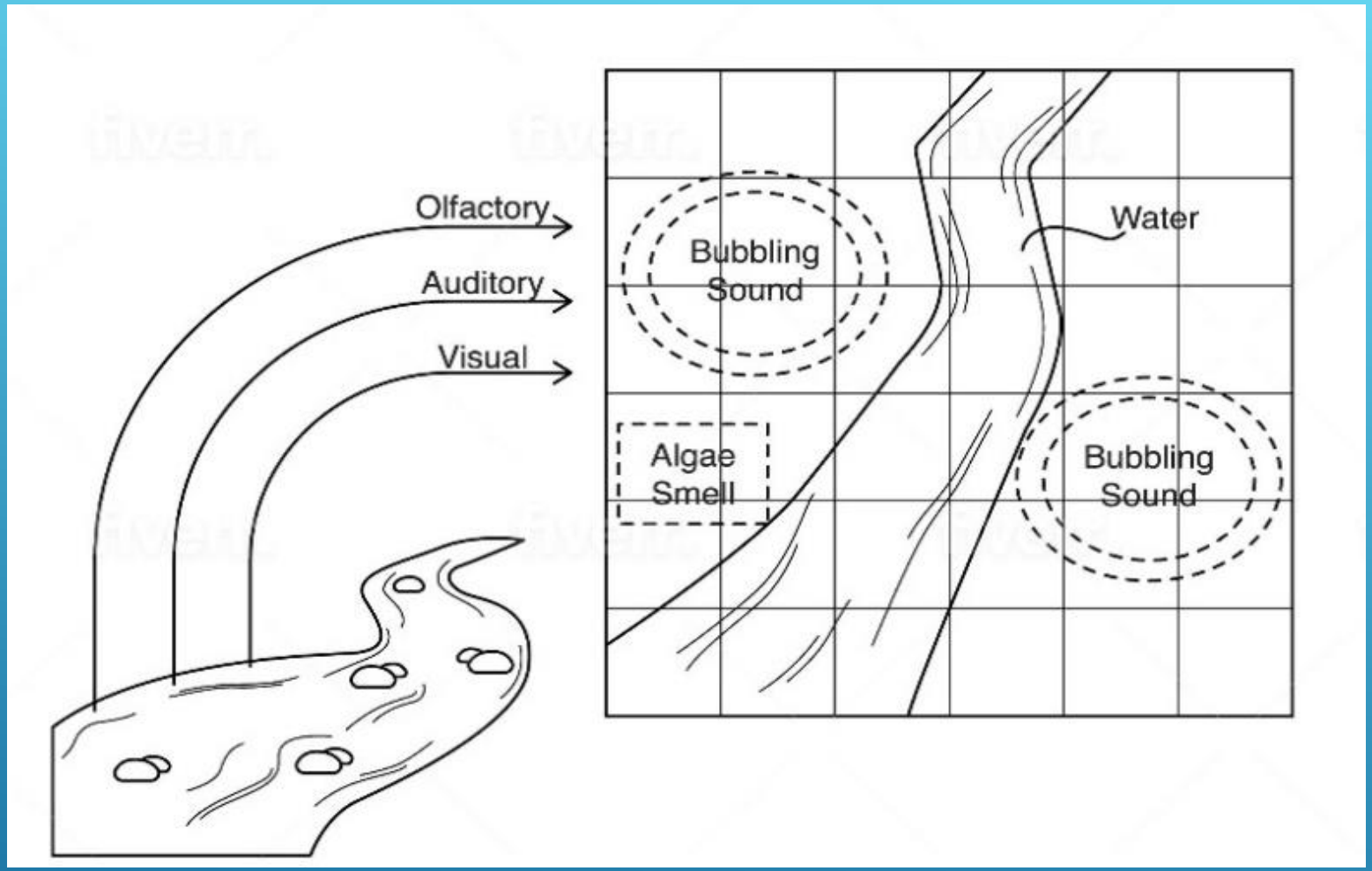

Local Visual
Navigation Map Match
Bubbling
Sound
Water
Algae
Smell
Bubbling
Sound
Navigation
Map A
Local Visual
Navigation
Map Match
Water
Green
Navigation
Map B
Brown
Local Olfactory
Navigation
Map Match
Local Auditory
Navigation
Map Match
Local Auditory
Navigation
Map Match
Water
Algae
Smell
Navigation
Map D
Bubbling
Sound
Water
Algae
Smell
Bubbling
Sound
Navigation
Map A
Bubbling
Sound
Water
Bubbling
Sound
Navigation
Map C


Olfactory
Auditory
Visual
Bubbling Sound
Water
Algae Smell
Bubbling Sound

The Binding Problem (Feldman, 2013):

- General coordination of objects and activities
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1. Sub-problem: General coordination of objects and activities

Use of navigation maps as a basic data element	Instinctive Primitives and Learned Primitives are applied against objects on the current navigation map	As such, a coordination of objects and activities occurs

2. Sub-problem: The subjective unity of perception

Best match navigation map represents the CCA2's perception of reality of the sensory scene in front of it	Current best match navigation map will be updated with current input sensory information, and represents CCA2's perception of the world	There is a subjective unity perception

3. Sub-problem: Visual Feature-Binding

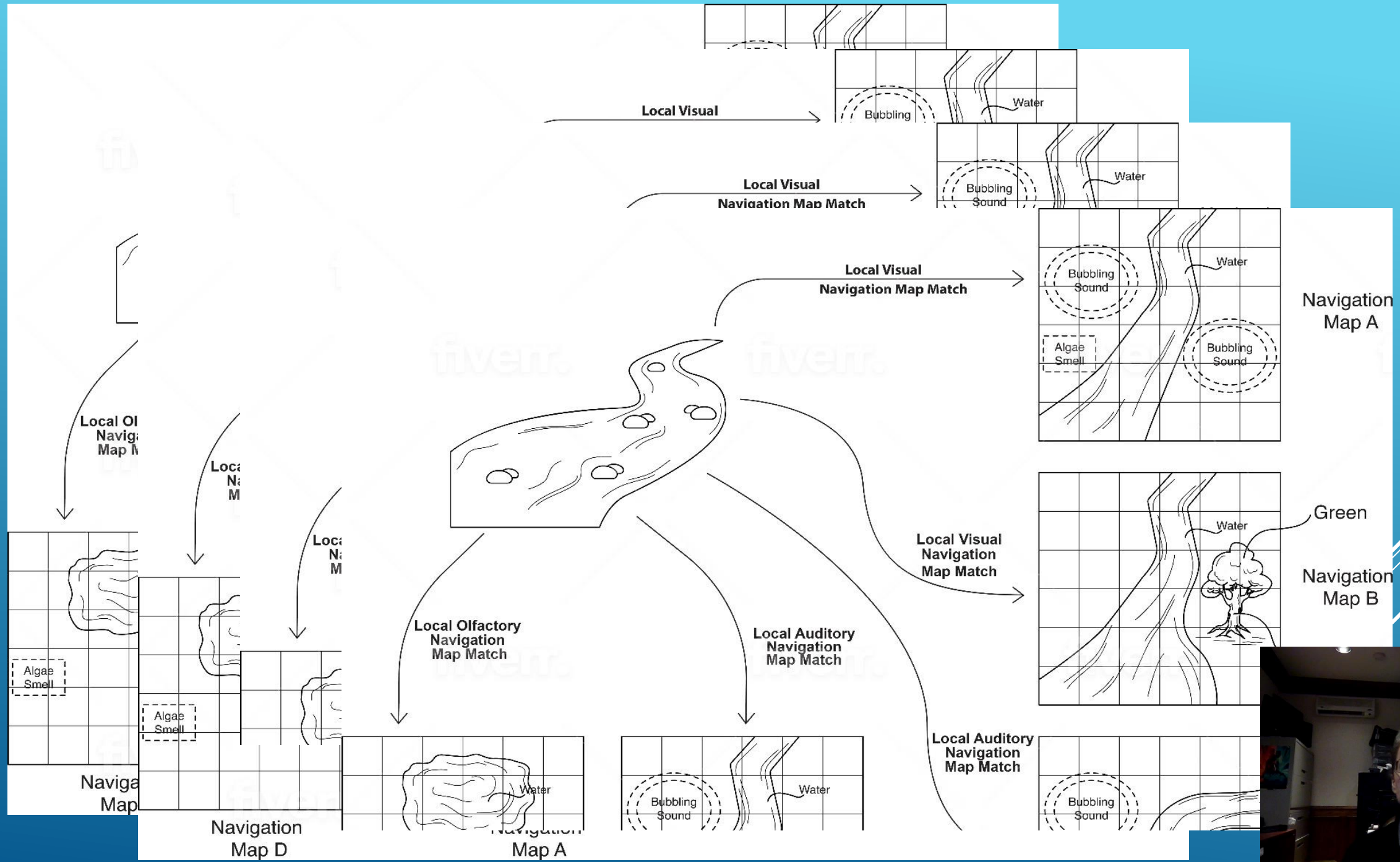
Spatially mapping visual features onto a spatial navigation map solves this binding sub-problem	No longer require a binding language; rather, binding occurs in the Vectors Association module and the Navigation Module

4. Sub-problem: Binding of Words Allow Reasoning

Verbs and nouns provide explanations to the user		Explanations generated via saved navigation maps

Most definitions of the 'Binding Problem' do not take time into account, ie, binding changes

- However, CCA2 shows changes in sensory inputs with time, that *must* bind time also
- **CCA3** – bind space time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Algae Smell
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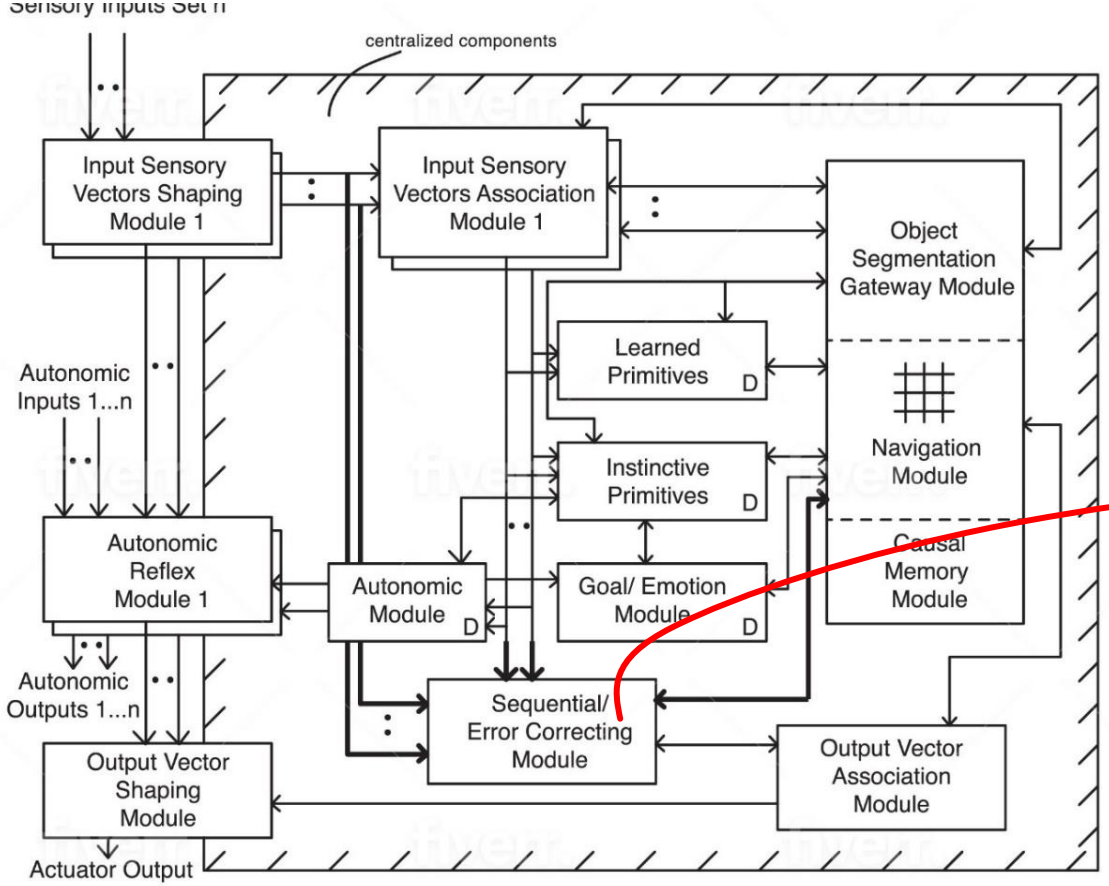
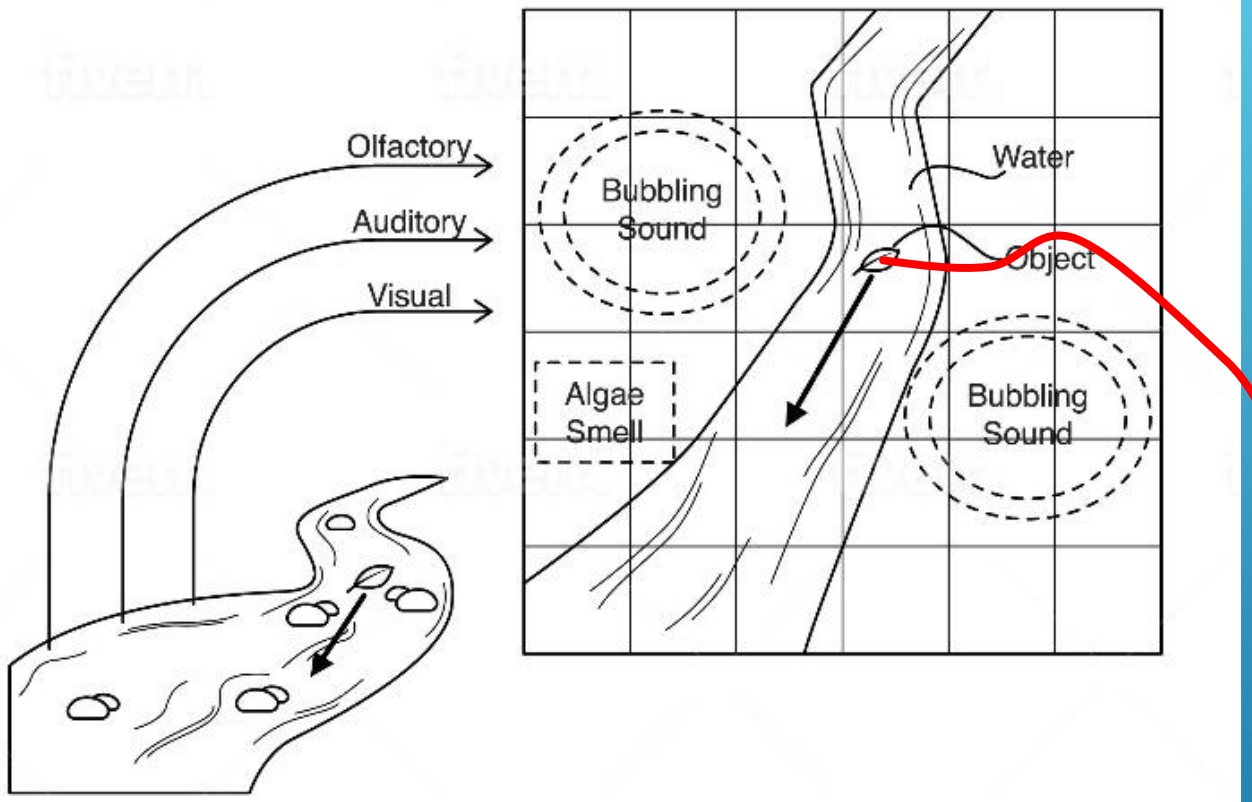
Navigation Map A
Local Visual
Navigation Map Match
Water
Green
Navigation Map B
Local Olfactory Navigation Map Match
Local Auditory Navigation Map Match
Local Auditory Navigation Map Match
Algae Smell
Algae Smell
Water
Bubbling Sound
Water
Bubbling Sound
Navigation Map D
Map A

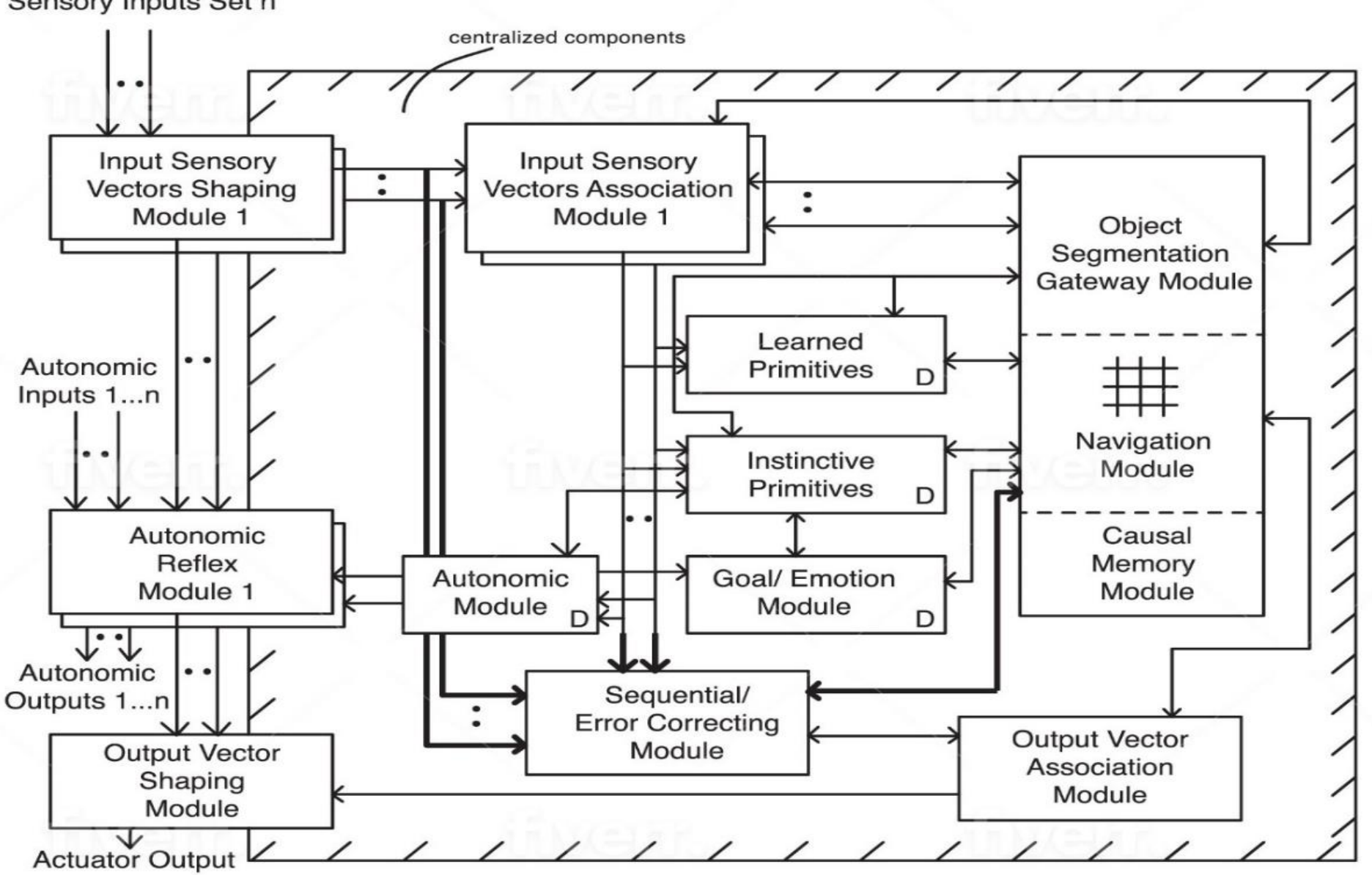


- CCA2 – binding of space
- CCA3 – need to bind changes with time also

GENERATE **MOTION PREDICTION VECTORS**



CCA3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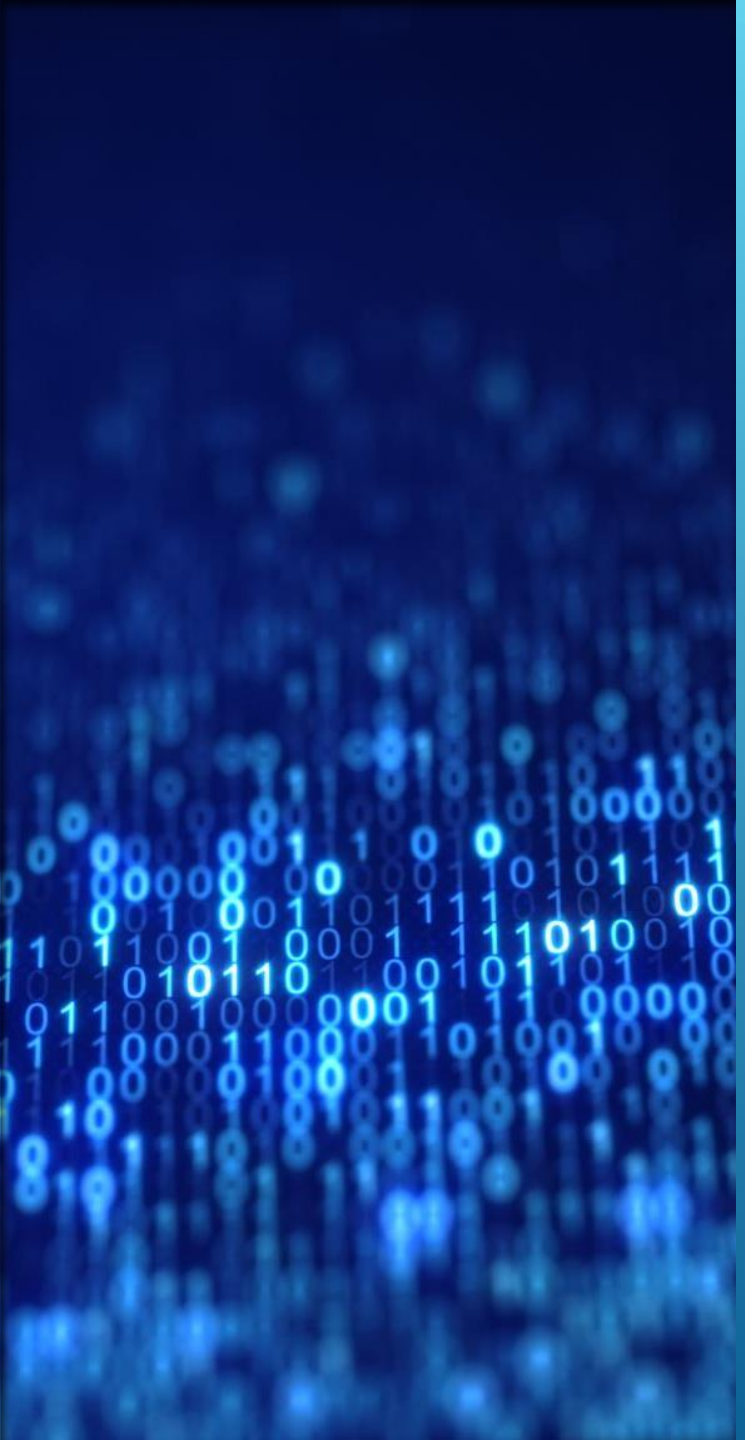

BRIEF OVERVIEW:

CCA3 SIMULATION SOFTWARE – STRUCTURE

….continued in VIDEO 2

balloon from powerpoint stock image