CAUSAL COGNITIVE ARCHITECTURE 2 (CCA2): A SOLUTION TO THE BINDING PROBLEM

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- BICA Workshop at IVA-2021
-
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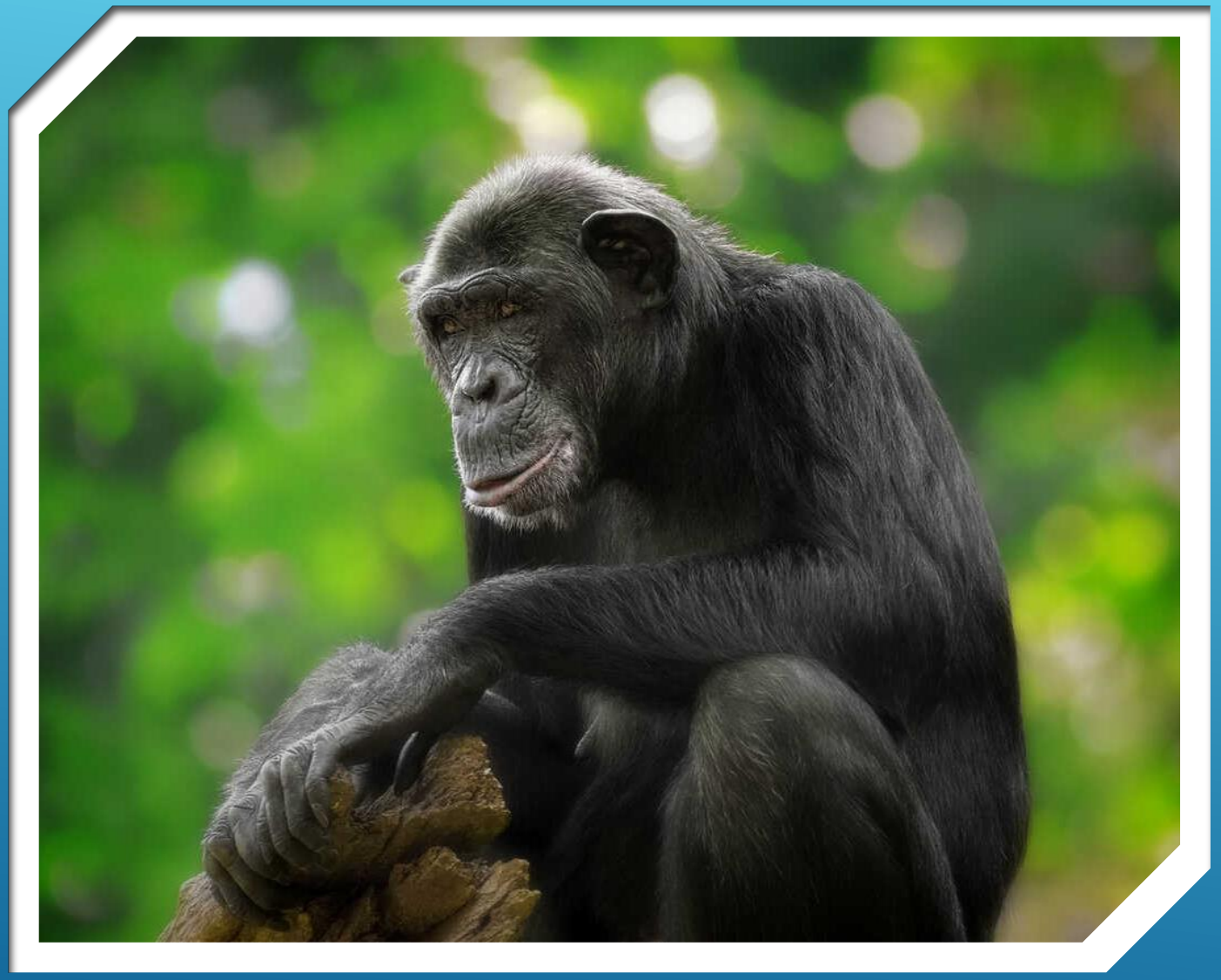
Why another Cognitive Architecture?

- Lots of models
- All consider how cognition can occur
- But…. none really considered the issues I thought were important….

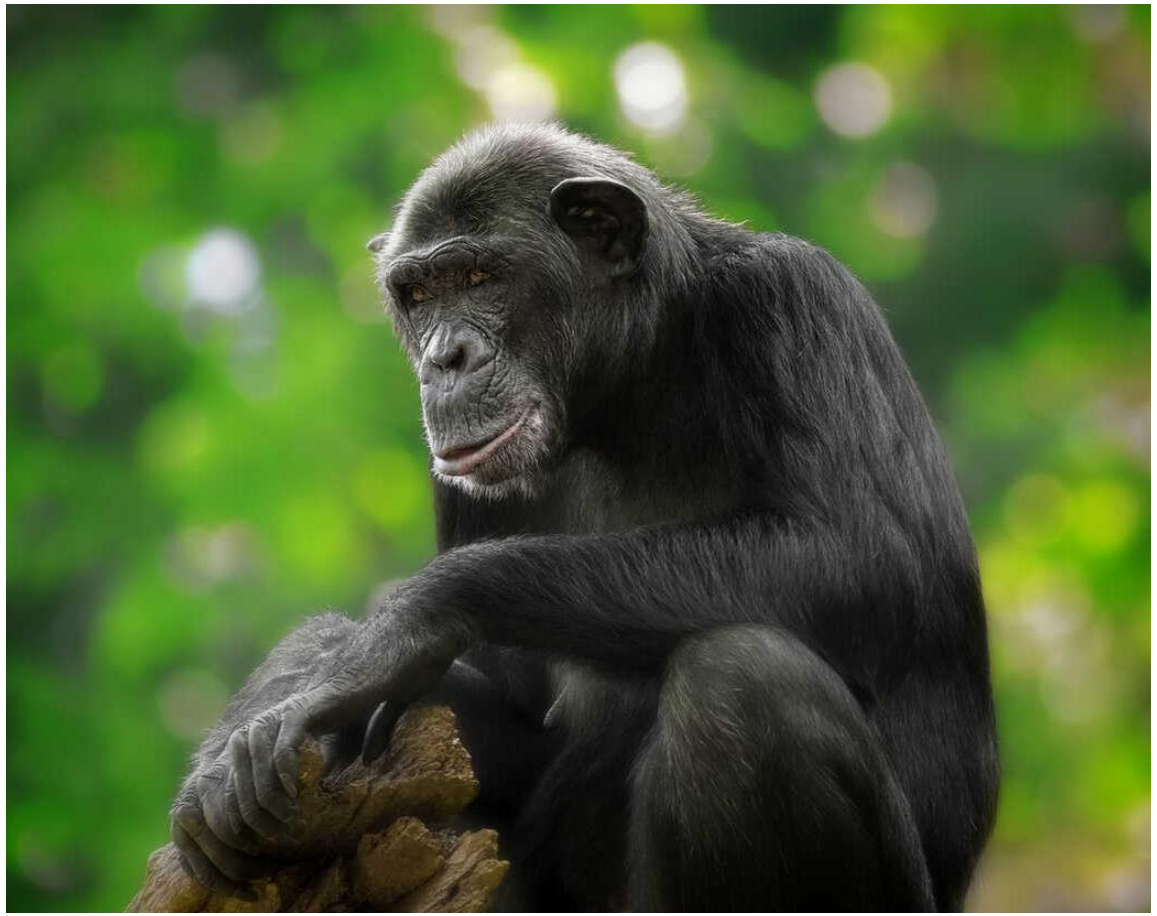
WHY SUCH A HIGH PREVALENCE OF PSYCHOSIS IN HUMANS?

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



WHY NO PSYCHOSIS IN ANIMALS?

WHY NO FULL CAUSAL BEHAVIOR IN ANIMALS?

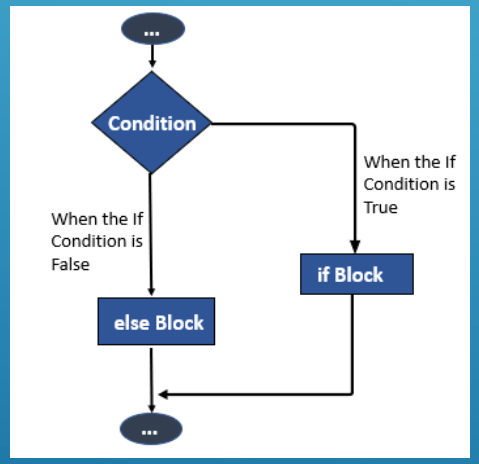


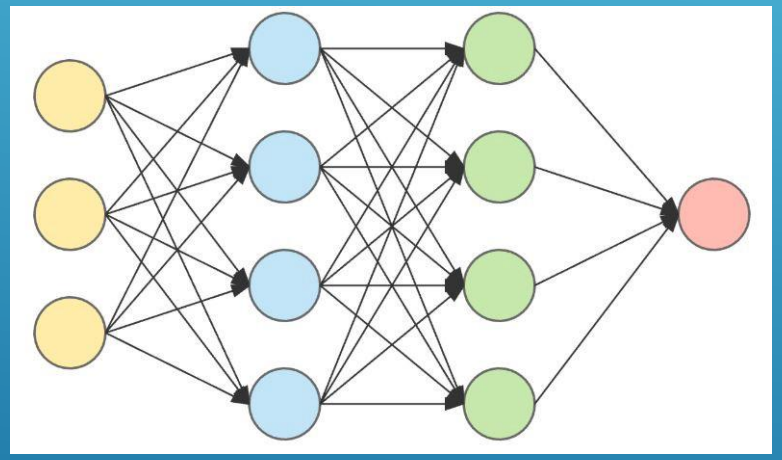
FOOD IN PLEXIGLASS TUBE

GRAVITY TRAP

CHIMPANZEE WITH STICK

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





Symbolic Logic GOFAI

Neural Networks

Navigation Maps

Navigation Maps with Causality

Navigation Maps:

Different way of making decisions

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

Navigation Maps:

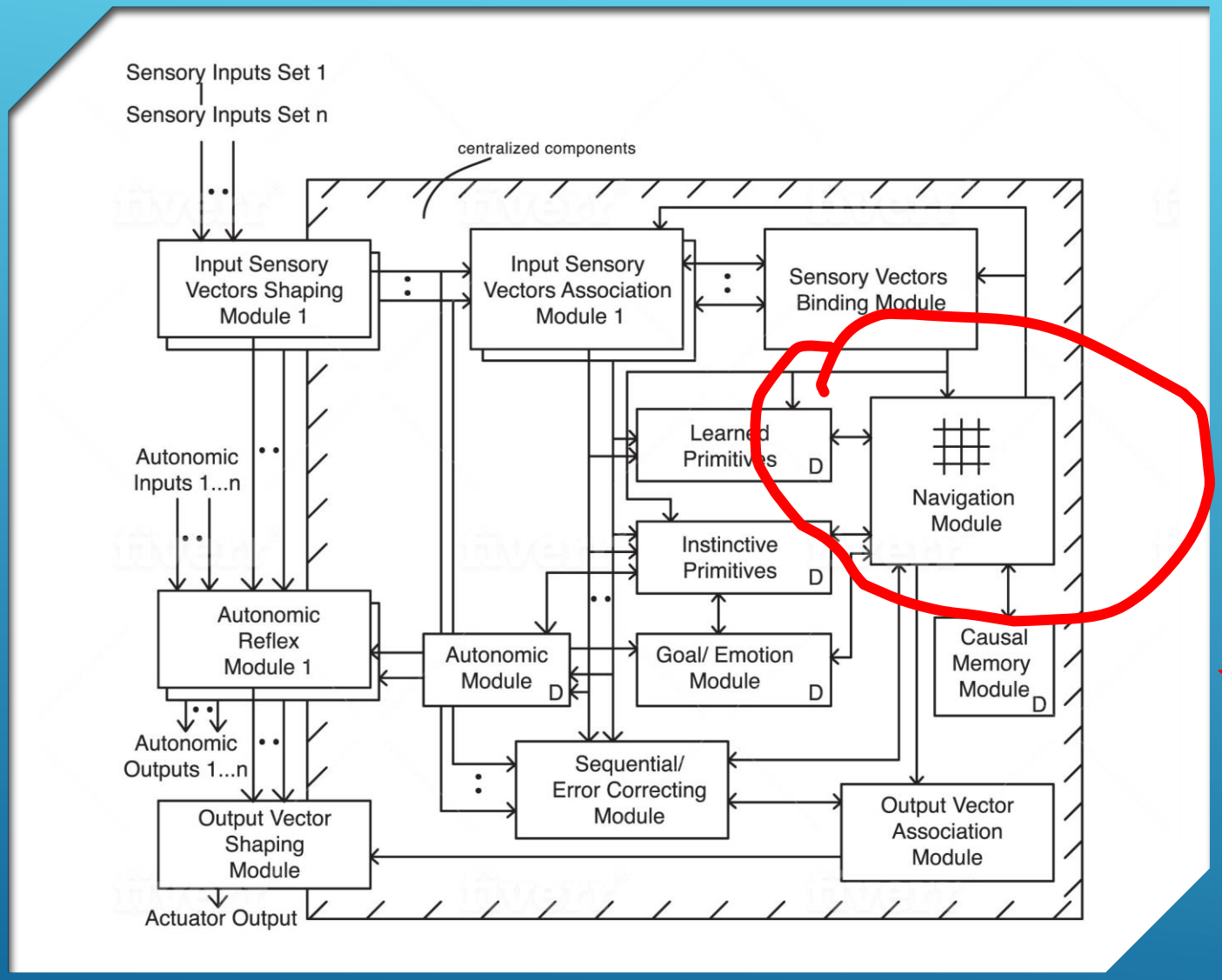
Vertebrates – all have formal navigation systems similar to mammalian hippocampus (place and grid cells)

Navigation Maps:

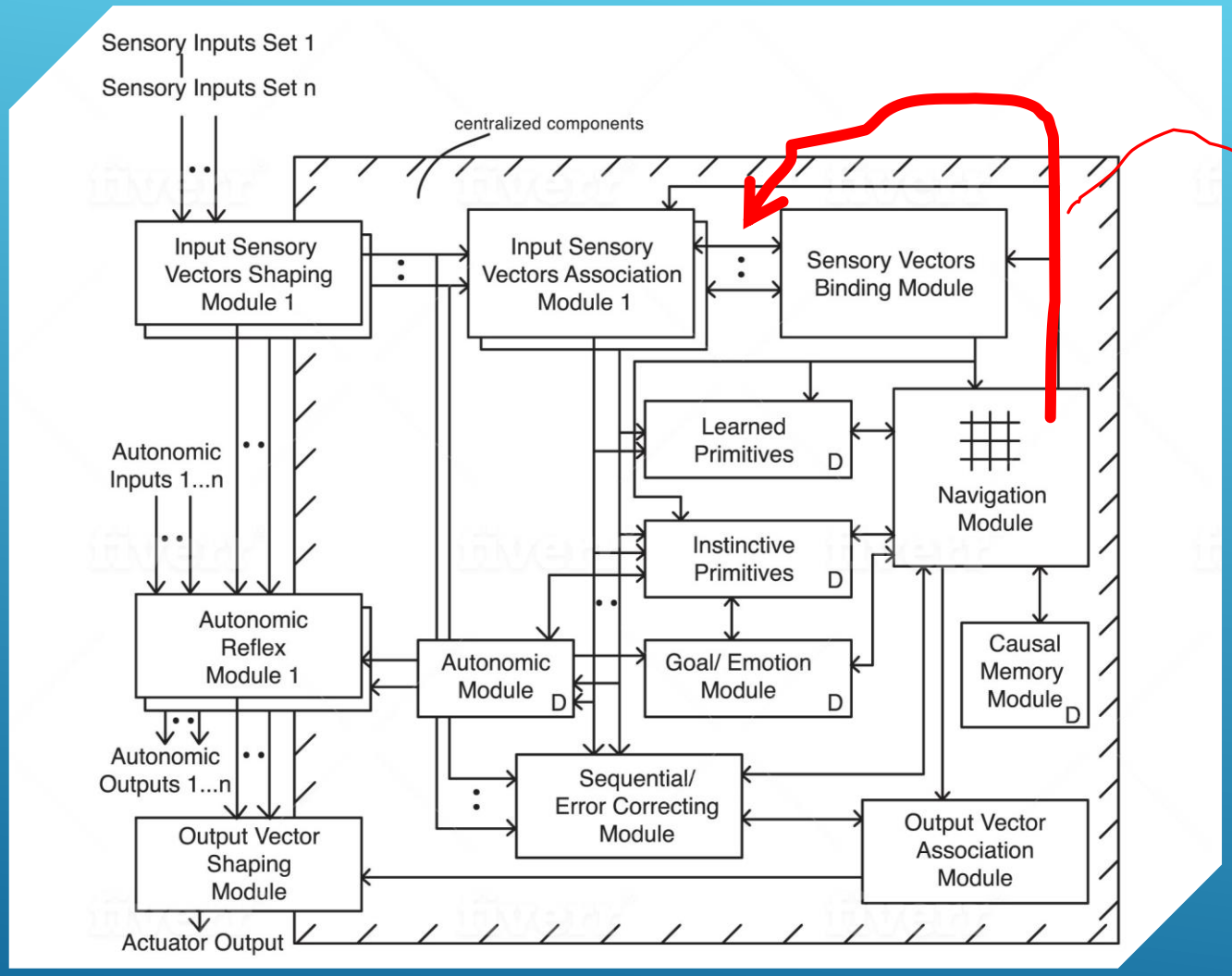
-use in an artificial cognitive architecture not just for navigation but all decisions

→Causal Cognitive Architecture

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



Works for toy problems



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

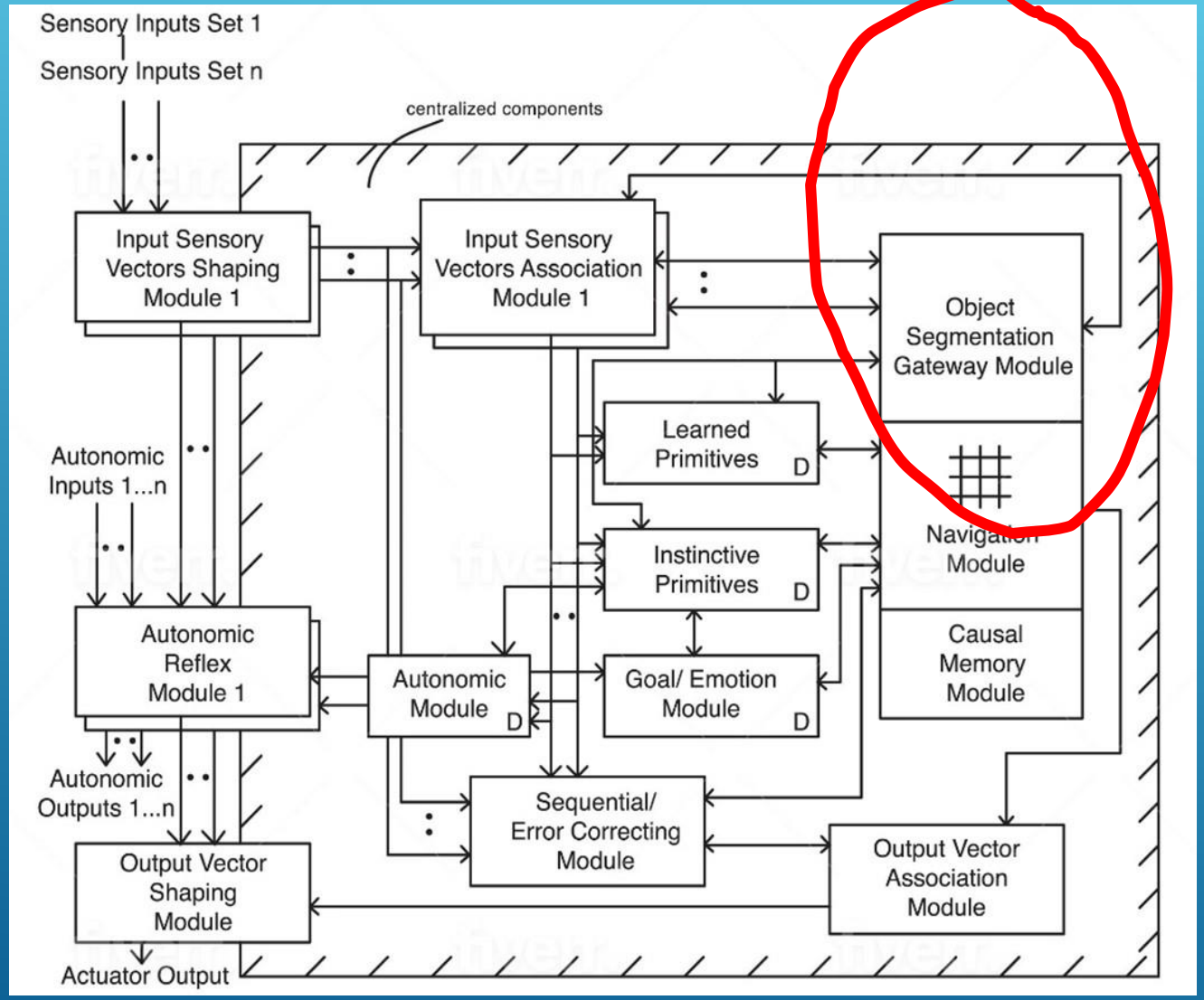
- CCA1 handles toy problems
- Want a more robust version of CCA1

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

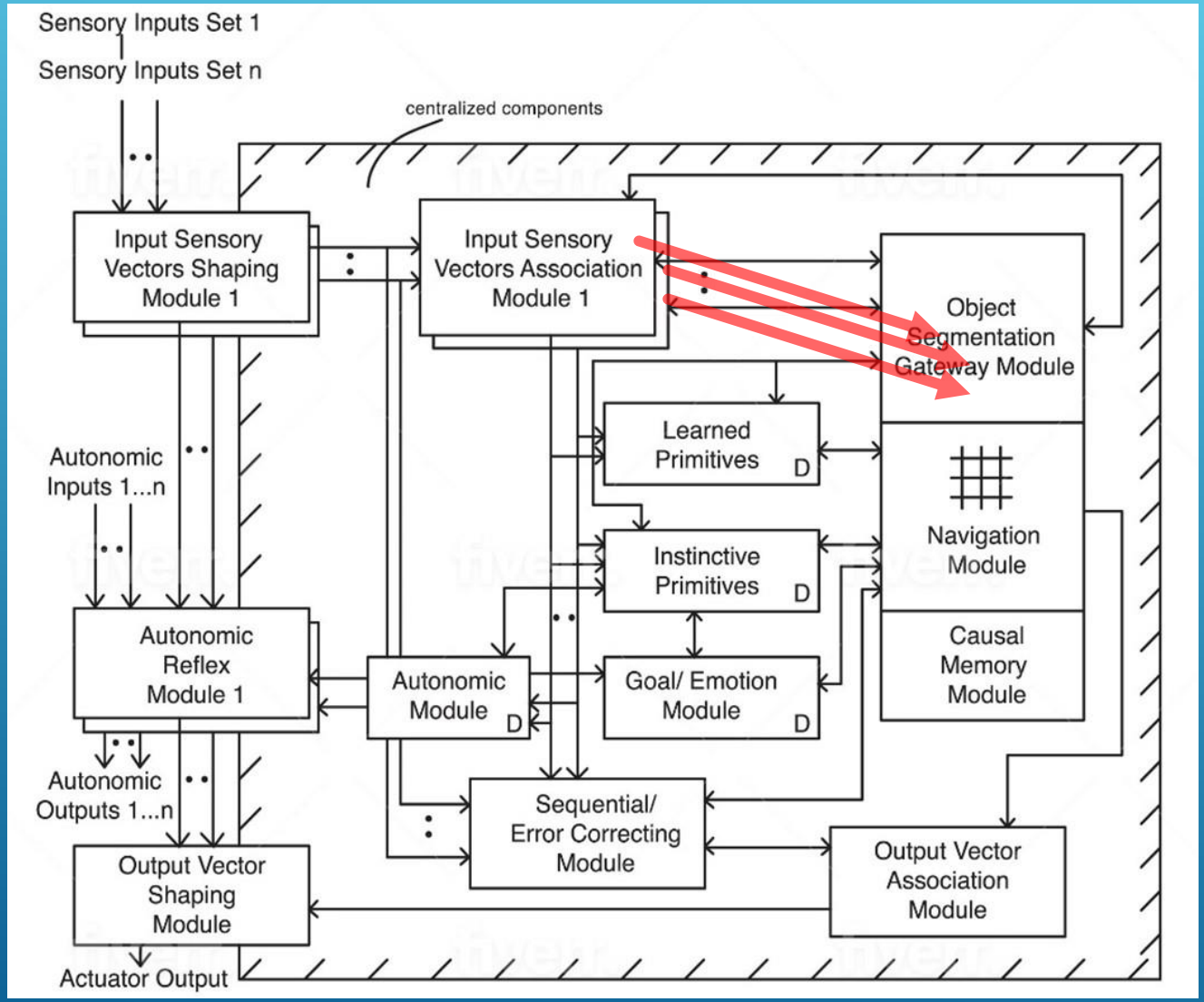
- Problem is that Sensory Vectors Binding Module must output some vector which represents object/environment it has detected by fusing sensory features together

- **How to label different combinations?**
- **Need a binding language of sorts**

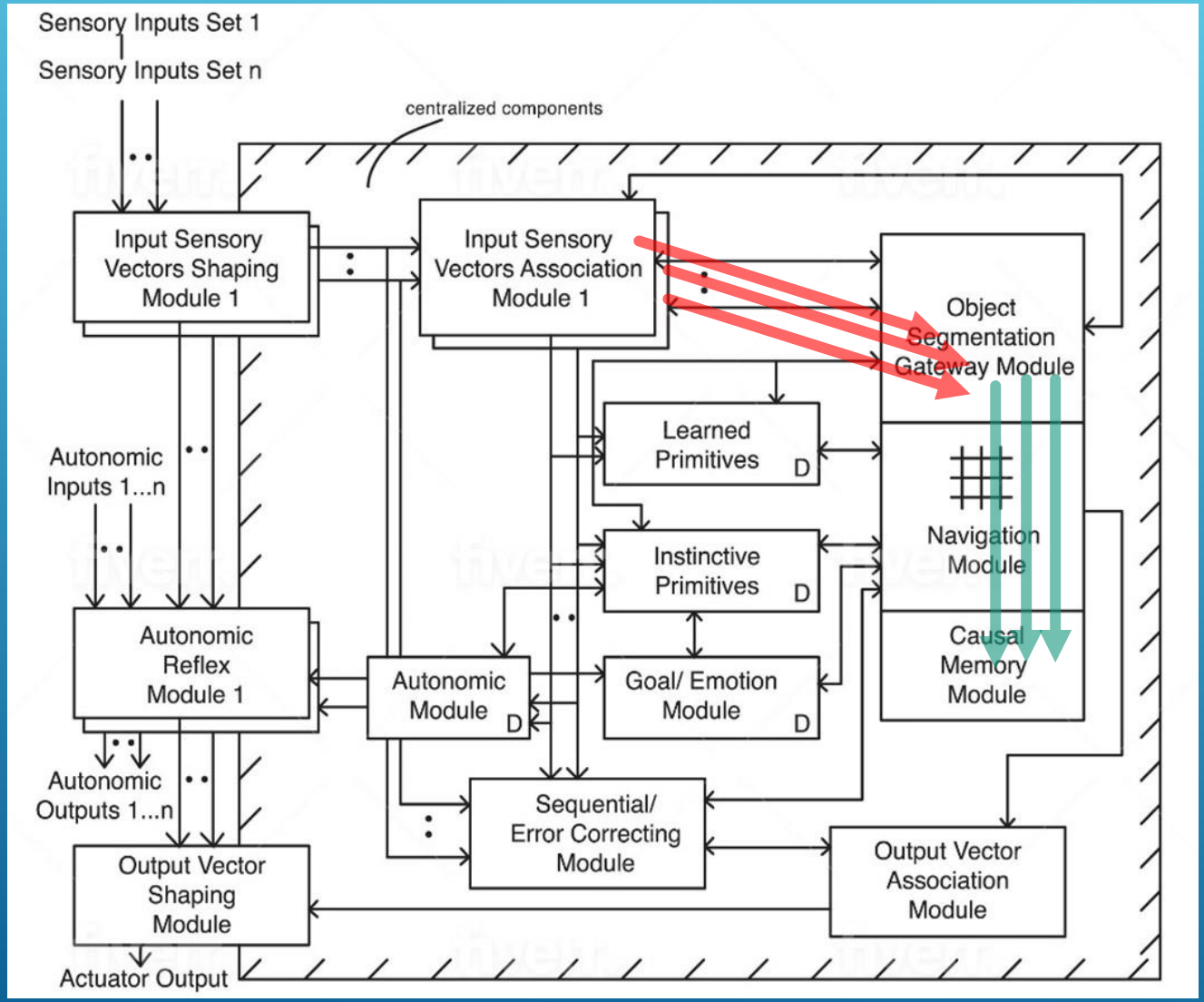
To handle real world problems, the binding issue needs to be addressed



← 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
Navigation Module
Instinctive Primitives D
Causal Memory Module
Autonomic Inputs 1...n
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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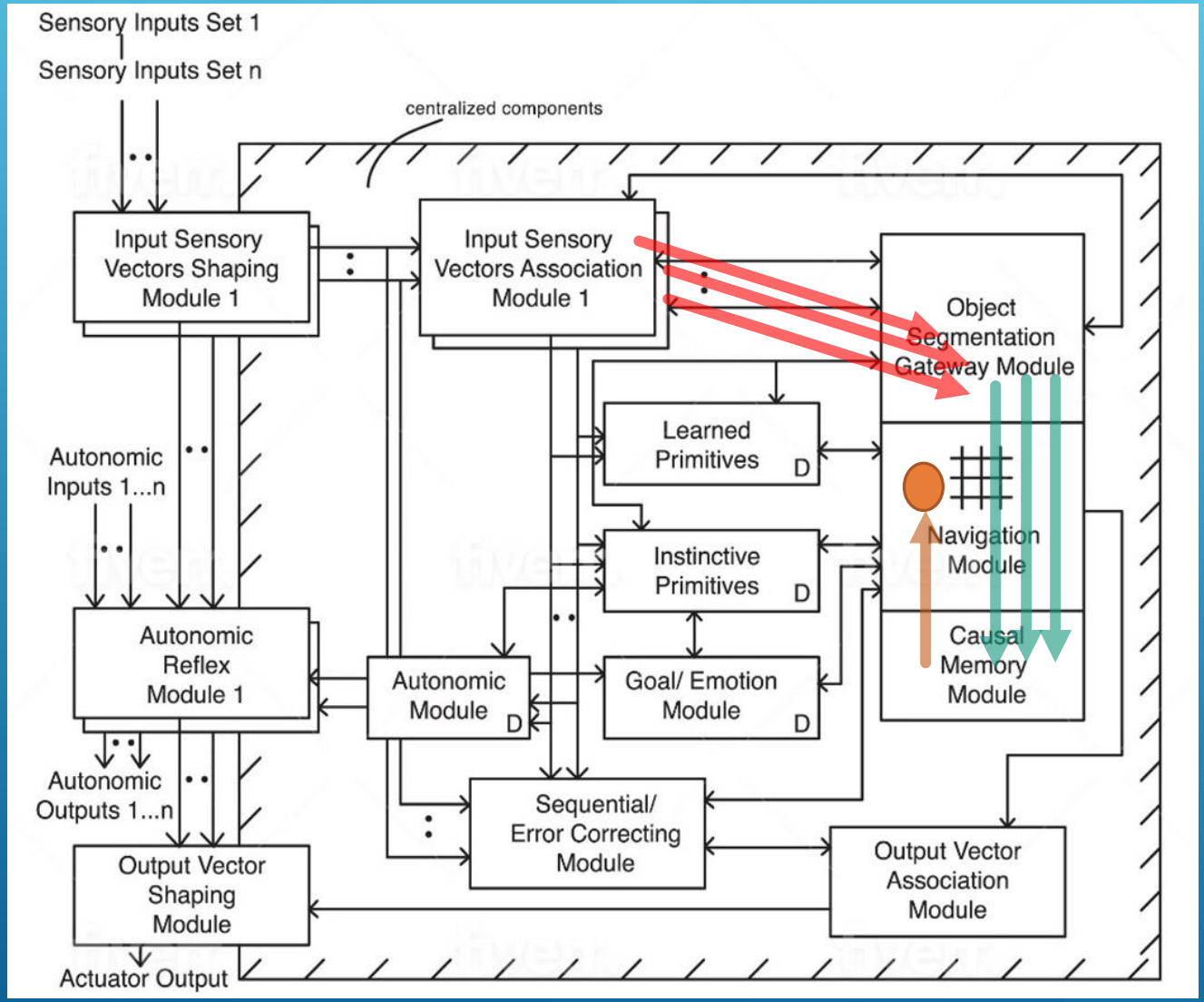
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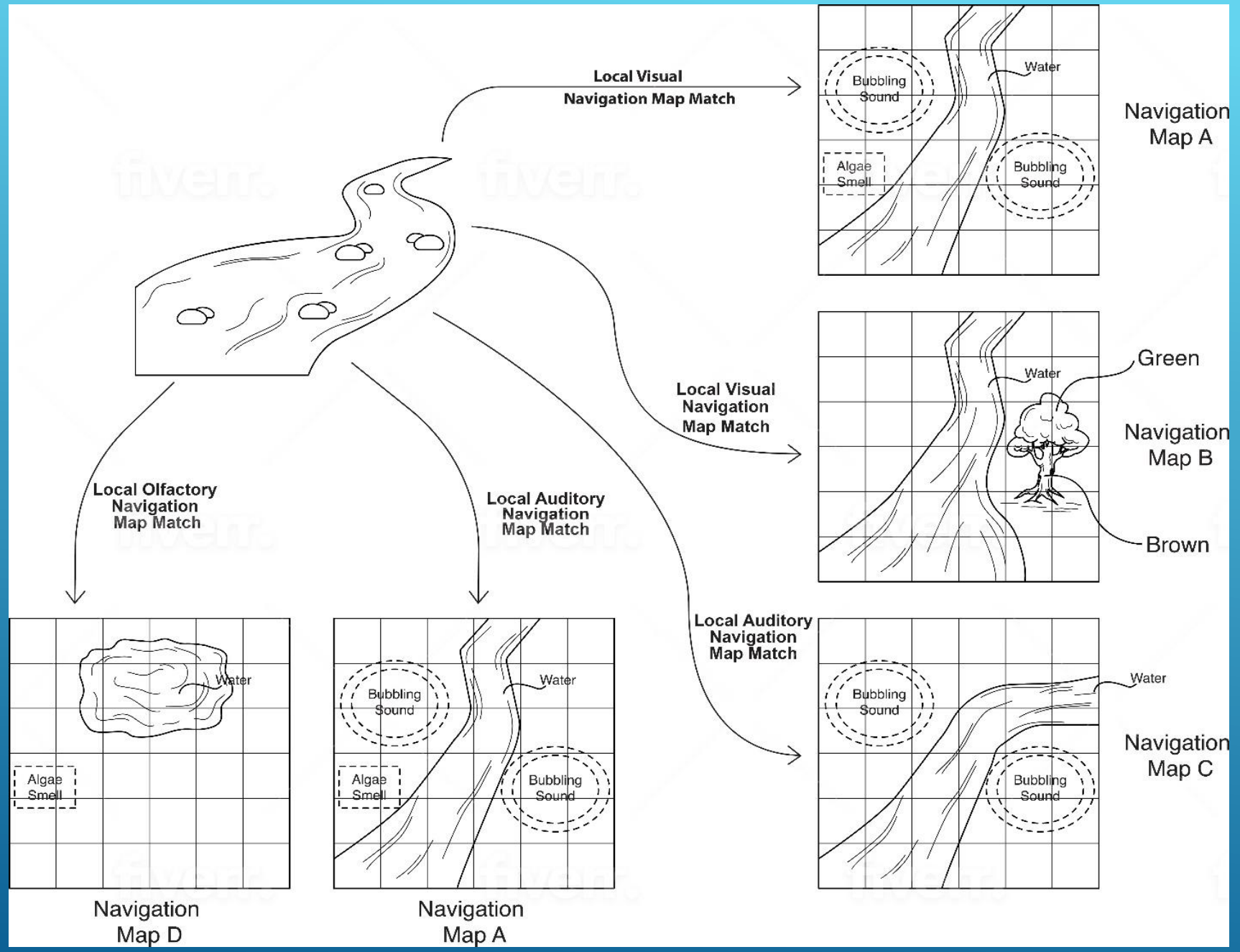
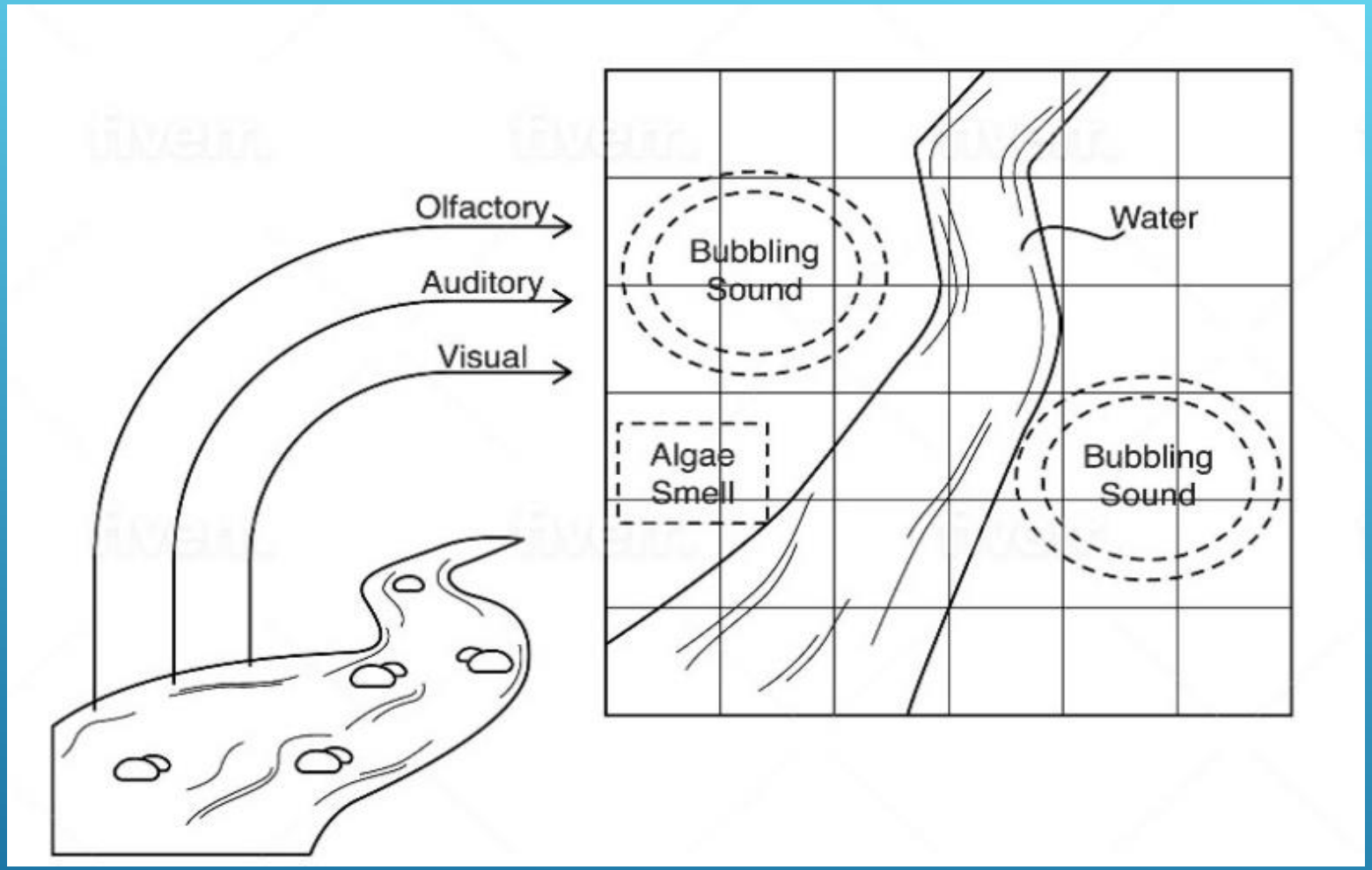
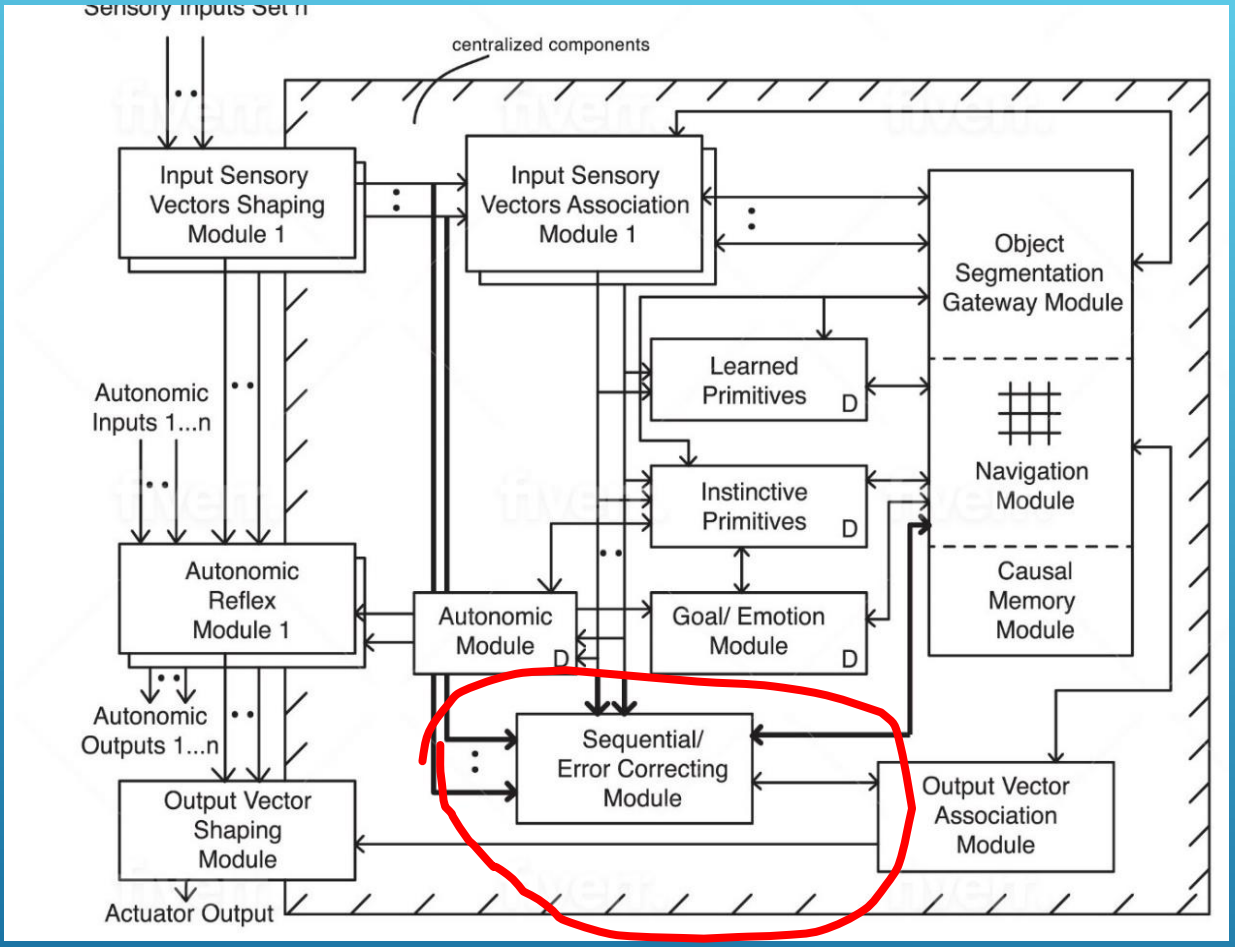

Local Visual
Navigation Map Match
Bubbling
Sound
Water
Algae
Smell
Bubbling
Sound
Navigation
Map A
Local Visual
Navigation
Map Match
Water
Green
Navigation
Map B
Brown
Local Olfactory
Navigation
Map Match
Local Auditory
Navigation
Map Match
Local Auditory
Navigation
Map Match
Water
Algae
Smell
Navigation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

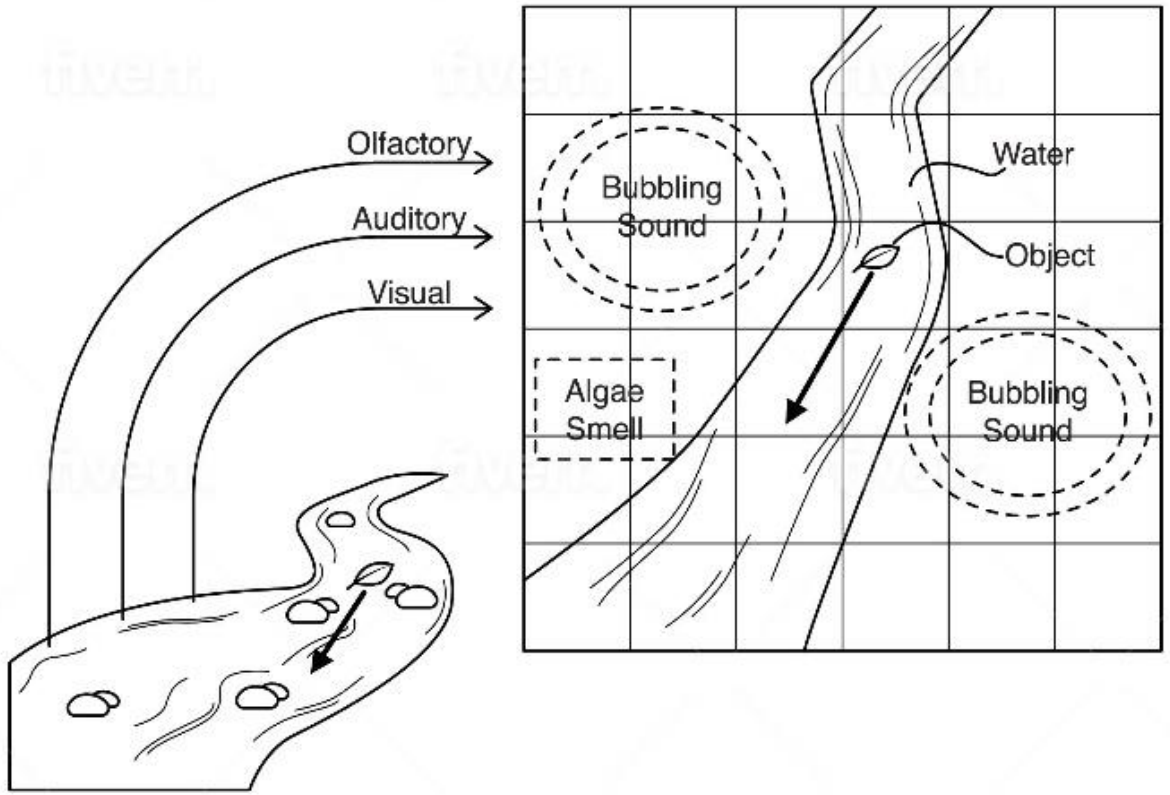
1. General coordination of objects and activities
2. The subjective unity of perception
3. Visual Feature-Binding
4. Variable Binding such as the binding of words in a sentence that allow reasoning

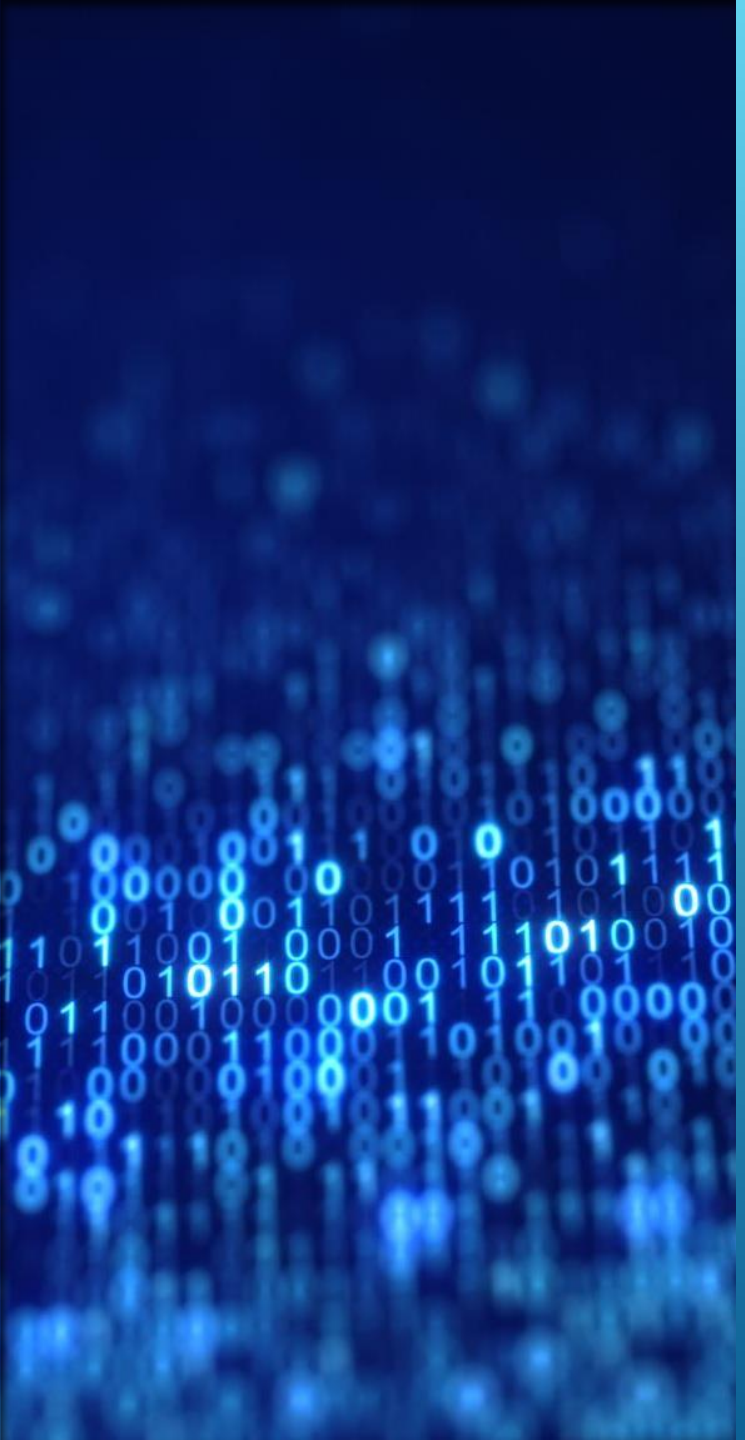


CCA3

Need to bind changes with time also

GENERATE MOTION PREDICTION VECTORS

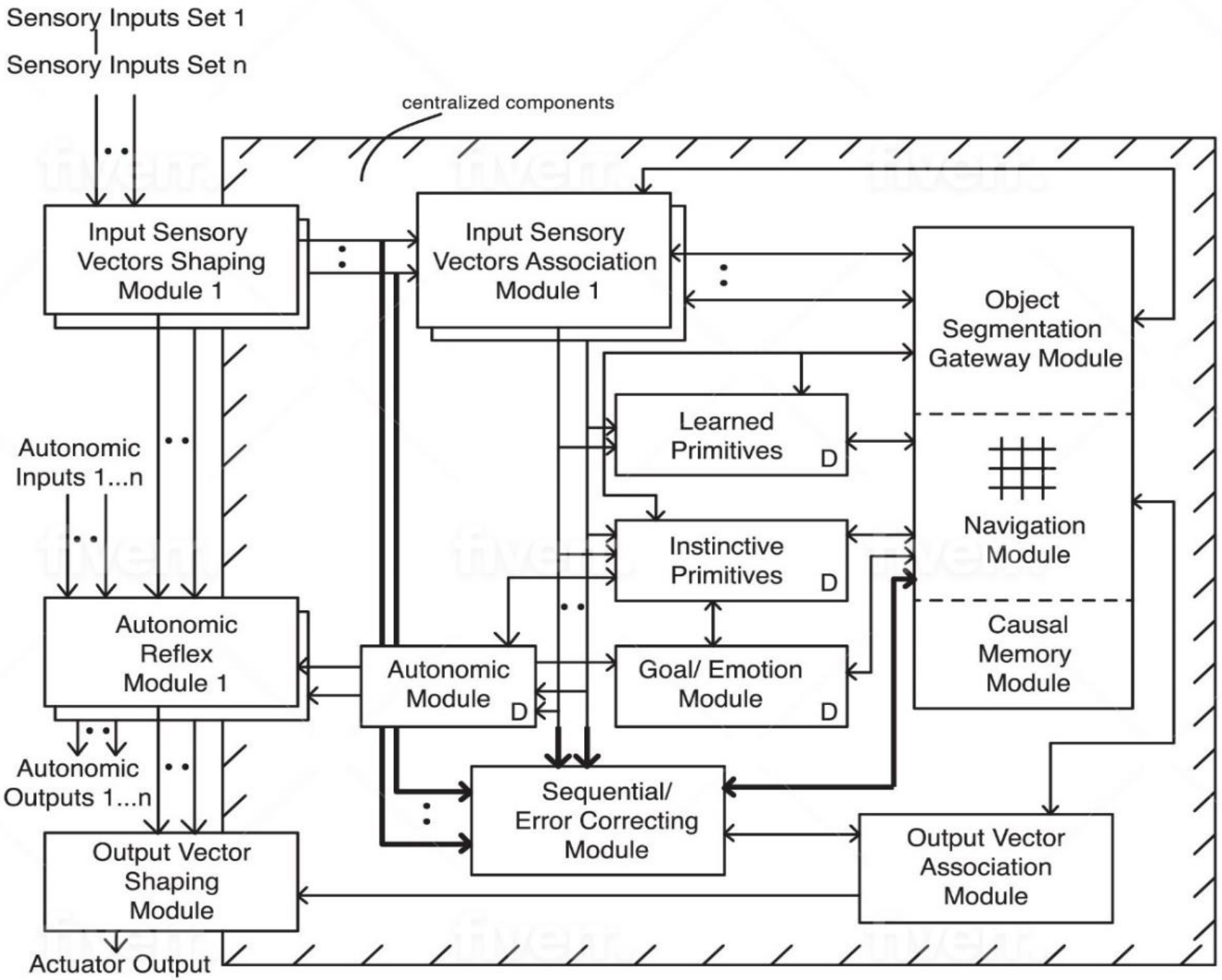




- **Demonstration of CCA3 Software**

- Walk-through of Source Code
- Live Demonstration of Code

CCA3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The Binding Problem (Feldman, 2013):

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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

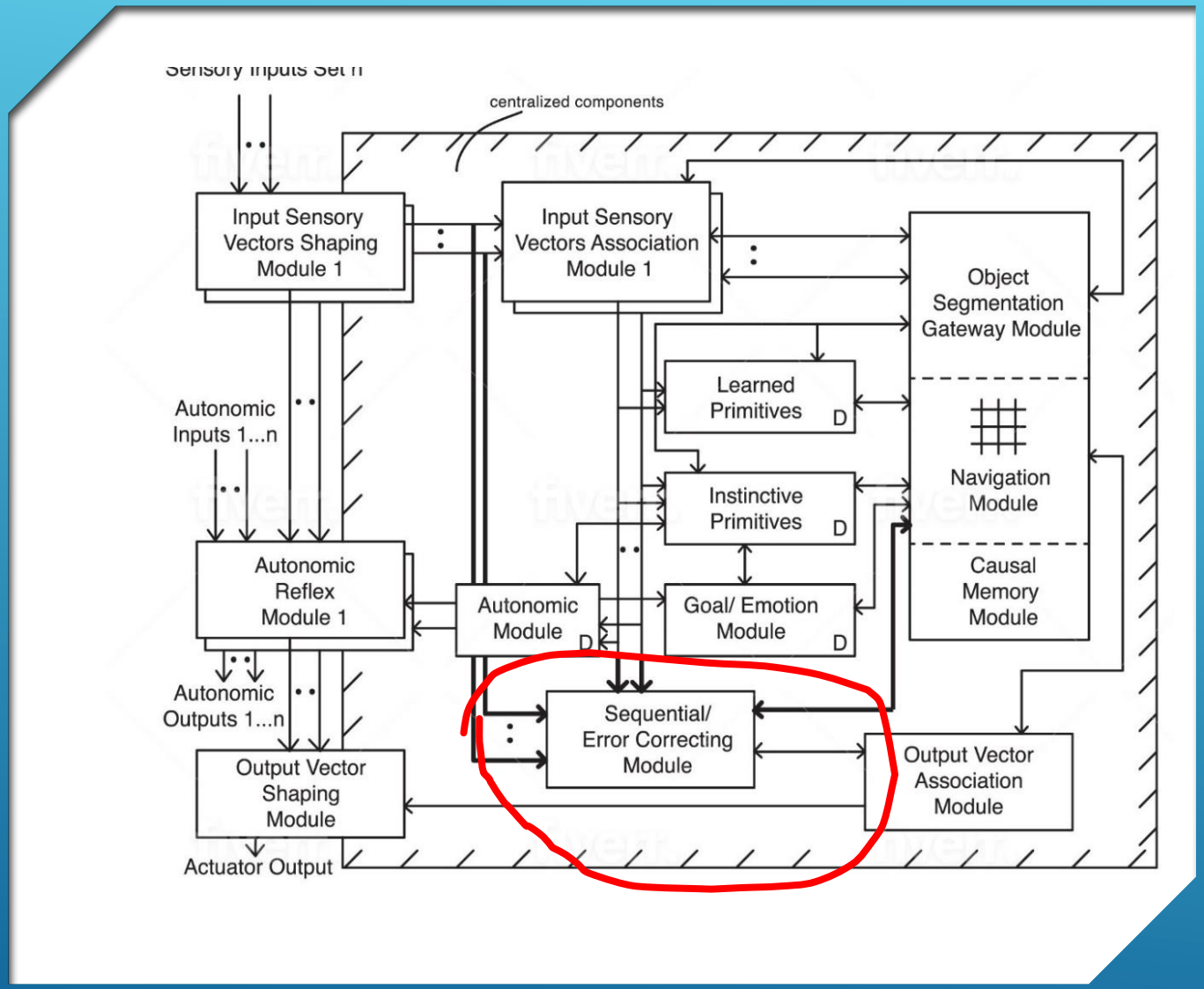
Spatially mapping visual features onto a spatial navigation map solves this binding sub-problem	No longer require a binding language; rather, binding occurs in the Vectors Association module and the Navigation Module

4. Sub-problem: Binding of Words Allow Reasoning

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

Most definition 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 *and* time



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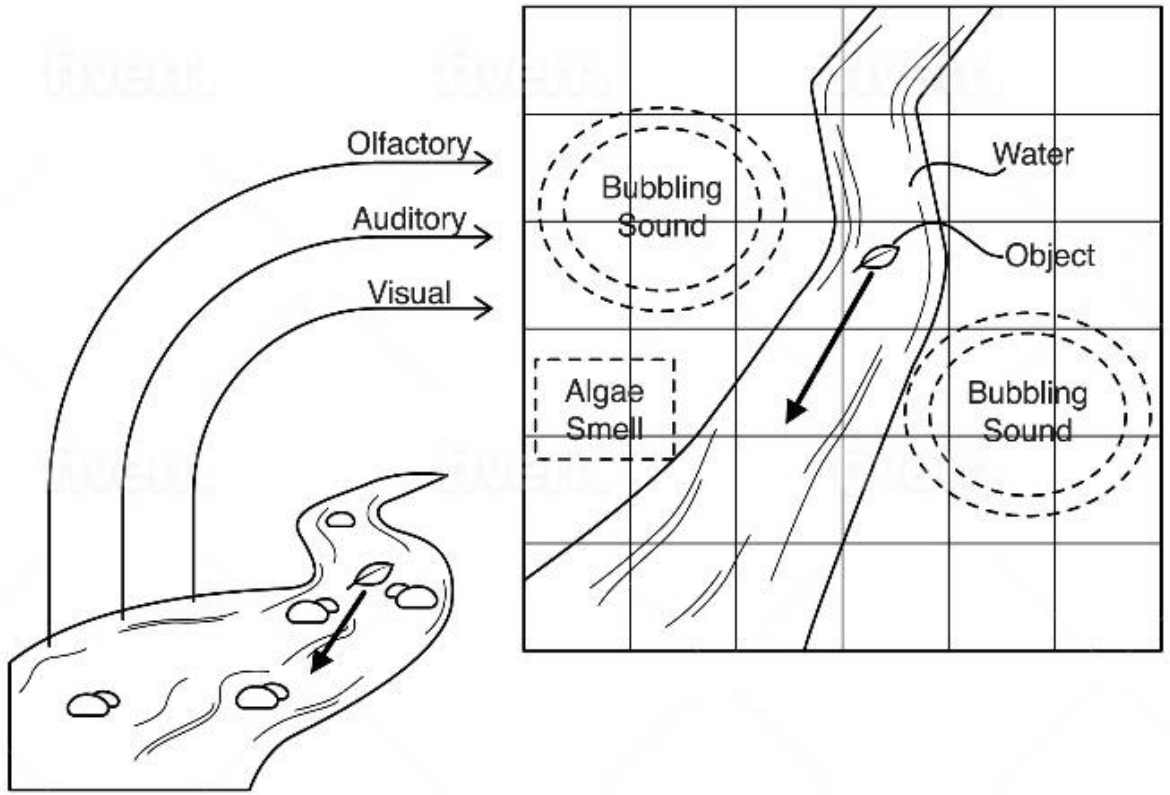

- **Desirable Properties of CCA3:**
- Seems able to go beyond toy problems
- Fully Causal Behavior – closes neurosymbolic gap
- Supports Schneider's psychosis hypothesis
- Solution to the Schizophrenia Paradox
- Analogies emerge automatically
- Explainability emerges automatically
- Lifelong ('continual') learning
- Abilities readily generalize to new and novel environments

- **CCA4:**
- Architecture: Input Sensory Vectors Association Modules merges into greater Navigation Module
- More robust Instinctive and Learned Primitives
- Open source the software if others interested

THANK YOU

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