On attempting to reify a few of the things we may mean by “consciousness” with code

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MIT

mit media lab

MIT Quest for Intelligence

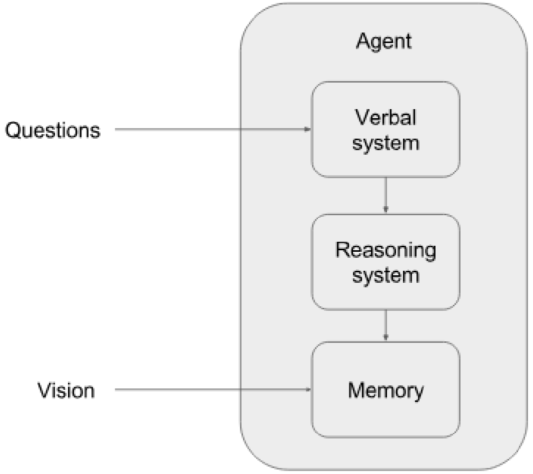
Why attempt to reify philosophy with code

- Lots of what philosophers think a lot about show up in CS/AI research
  - Mind, awareness, imagination, reasoning, consciousness, etc.
- CS/AI could benefit from a deeper understanding of philosophy
- Possibly benefit philosophy by bringing code-style concreteness
  - (TBD)

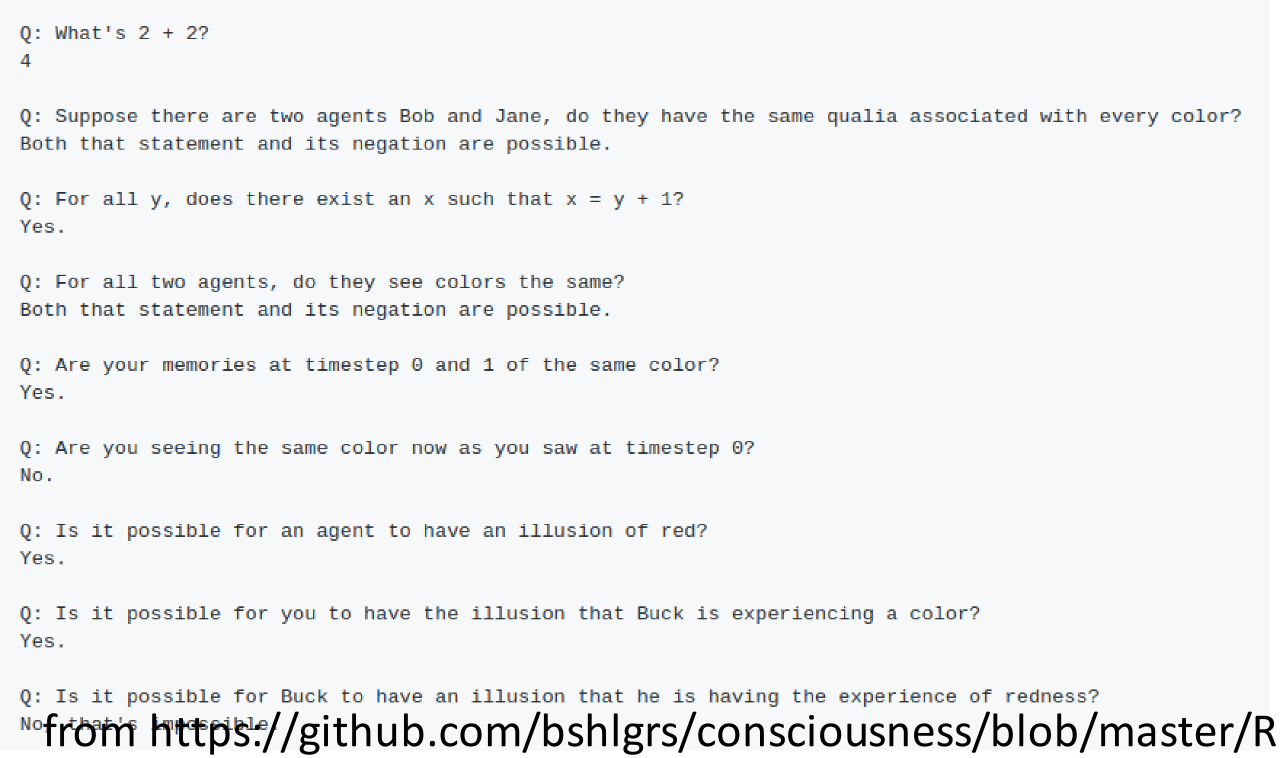
- (Disclaimer: our backgrounds are CS/AI)

Reifying philosophy with code

- Muehlhauser, Shlegeris: A Software Agent Illustrating Some Features of an Illusionist Account of Consciousness
- An agent that observes the world and uses a theorem prover to answer questions asked of it



from shlegeris.com



```
Q: What's 2 + 2?
4

Q: Suppose there are two agents Bob and Jane, do they have the same qualia associated with every color?
Both that statement and its negation are possible.

Q: For all y, does there exist an x such that x = y + 1?
Yes.

Q: For all two agents, do they see colors the same?
Both that statement and its negation are possible.

Q: Are your memories at timestep 0 and 1 of the same color?
Yes.

Q: Are you seeing the same color now as you saw at timestep 0?
No.

Q: Is it possible for an agent to have an illusion of red?
Yes.

Q: Is it possible for you to have the illusion that Buck is experiencing a color?
Yes.

Q: Is it possible for Buck to have an illusion that he is having the experience of redness?
No, that's impossible.
```

from https://github.com/bshlgrs/consciousness/blob/master/README.md

Reifying philosophy with code

Reifying philosophy with code

- Searle’s view of the relationship between consciousness and brain states
    - Consciousness is causally reducible to brain states but consciousness is ontologically irreducible to brain states

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  - Consciousness is causally reducible to brain states but consciousness is ontologically irreducible to brain states
    - ...what does that mean?

Reifying philosophy with code

- Searle’s view of the relationship between consciousness and brain states
  - Consciousness is causally reducible to brain states but consciousness is ontologically irreducible to brain states
    - ...what does that mean?
- Generally is some confusion
  - Enough disagreement that Searle wrote the paper: “Why I’m Not a Property Dualist”

What we're not doing

- Trying to propose a cognitive architecture
- Trying to propose a new AI or machine learning algorithm
- Trying to claim that the software agent is conscious
- Trying to convince anyone these are the correct/best/most useful definitions of mental states and brain states
- Trying to convince anyone Searle is right or wrong

What we're trying to do

- Create a software agent that is consistent with Searle’s view on consciousness
    - (or at least a simplified version of Searle’s view)

What we're trying to do

- Create a software agent that is consistent with Searle’s view on consciousness
    - (or at least a simplified version of Searle’s view)
- (Hopefully) gain a bit deeper understanding of what we may mean by consciousness, brain states, causal reduction, and ontological reduction along the way

Software Engineering, 101

- Requirements – what must the agent do
- Design – how will we build an agent to meet the requirements
- Implementation – the built agent consistent with the design

Agent requirements: unpacking Searle's view

- Consciousness is causally reducible to brain states
- Consciousness is ontologically irreducible to brain states

Agent requirements: unpacking Searle's view

- Brain state
  - The full physical-chemical state of the brain and nervous system
  - Third person, objective

Agent requirements: unpacking Searle's view

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  - Third person, objective
- Internal state
  - Representations, goals, rewards, observations, actions, etc.
  - Subjective

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  - Beliefs, desires, thoughts, perceptions, emotions, knowledge, etc.
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    - Subjective
- Mental state
    - Beliefs, desires, thoughts, perceptions, emotions, knowledge, etc.
    - First person, subjective
- Conscious mental state
    - A mental state in which it is "something it's like to be in"
    - First person, subjective character of experience, phenomenal

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Agent requirements: unpacking Searle's view

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- V2
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- V1
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Phenomena of type A are ontologically reducible to phenomena of type B
if and only if A’s are nothing but B’s

Ontologies in Computer Science

- Class-instance distinction

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Ontologies in Computer Science

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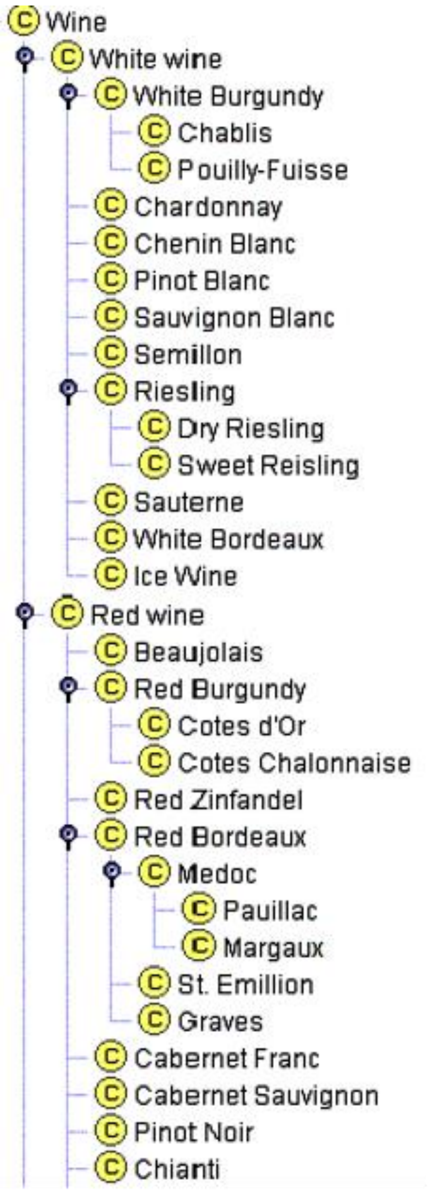

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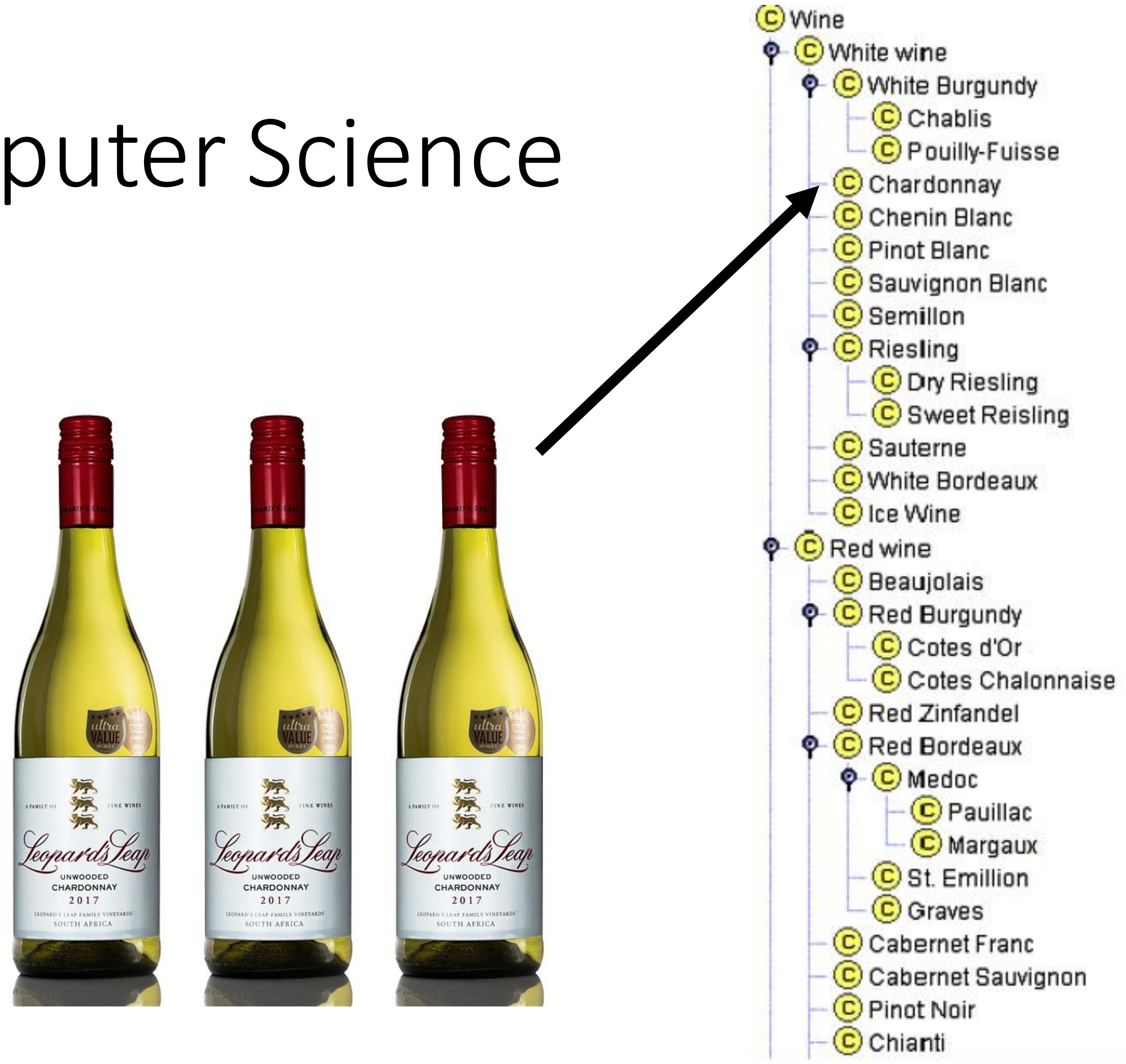

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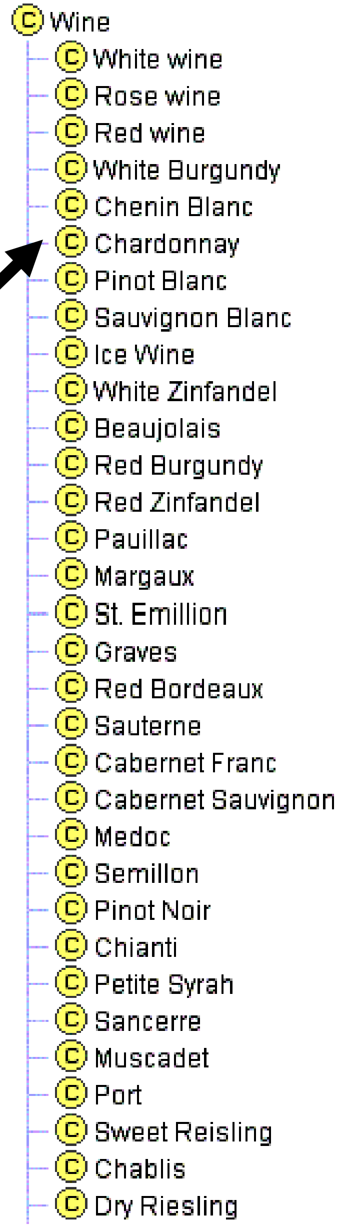

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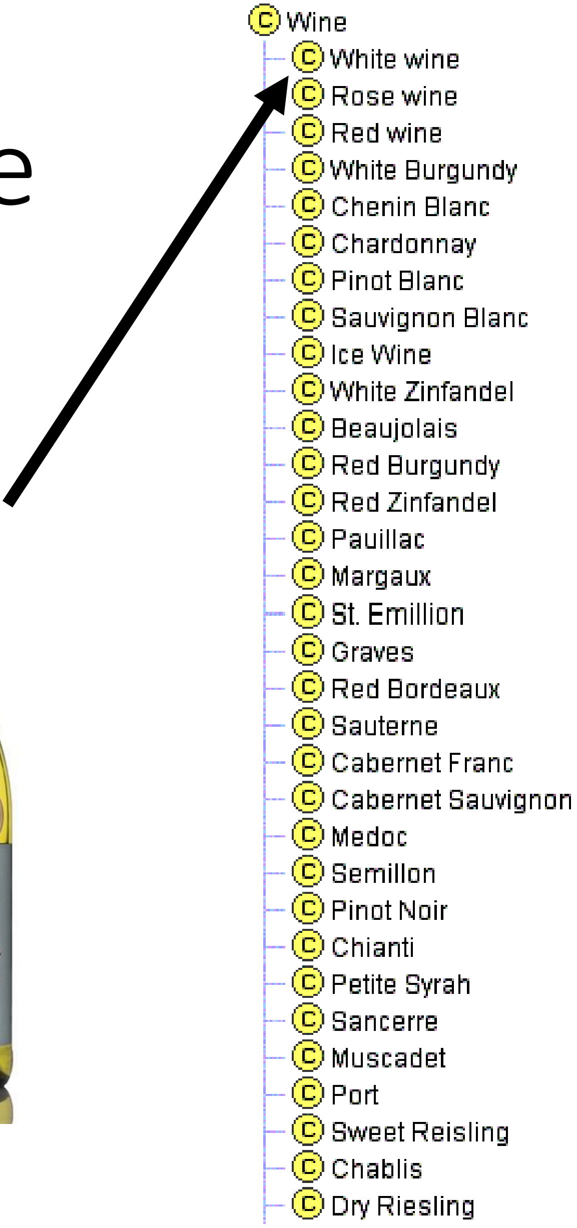

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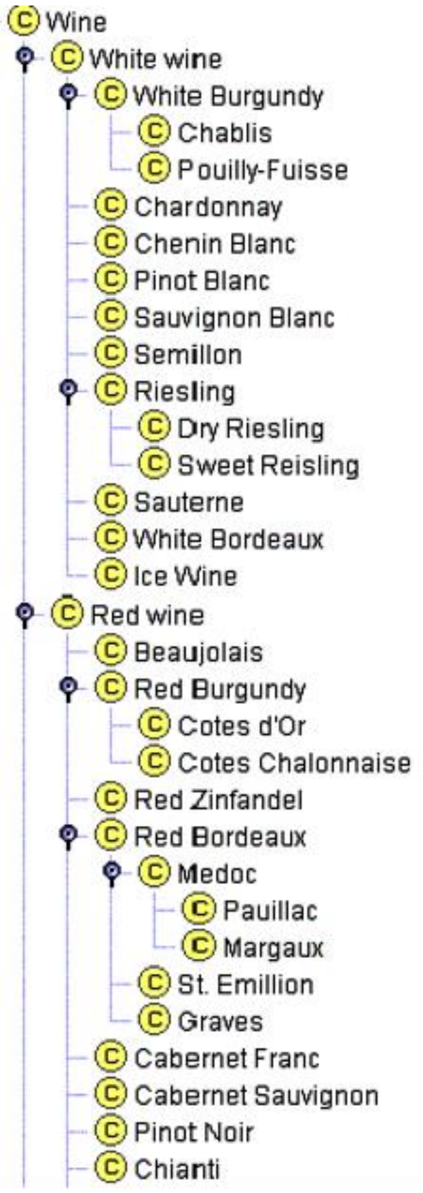

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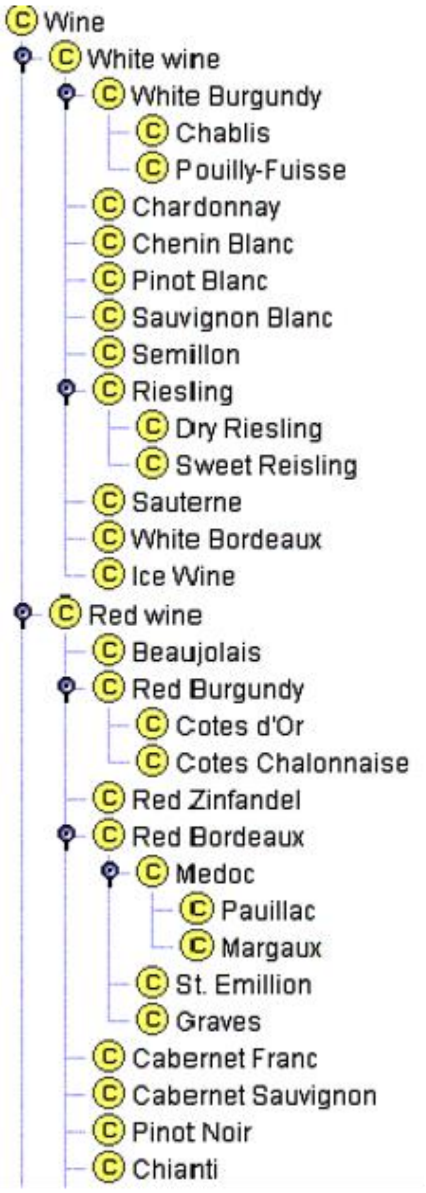
Ontologies in Computer Science

- Class-instance distinction
- Type-token distinction
  - "They drive the same car“
    - They drive the same car type
      - (a Toyota)
    - They drive the same car token
      - (the 2003 Toyota Corolla with VIN: 2QFBORHE4KP911561)



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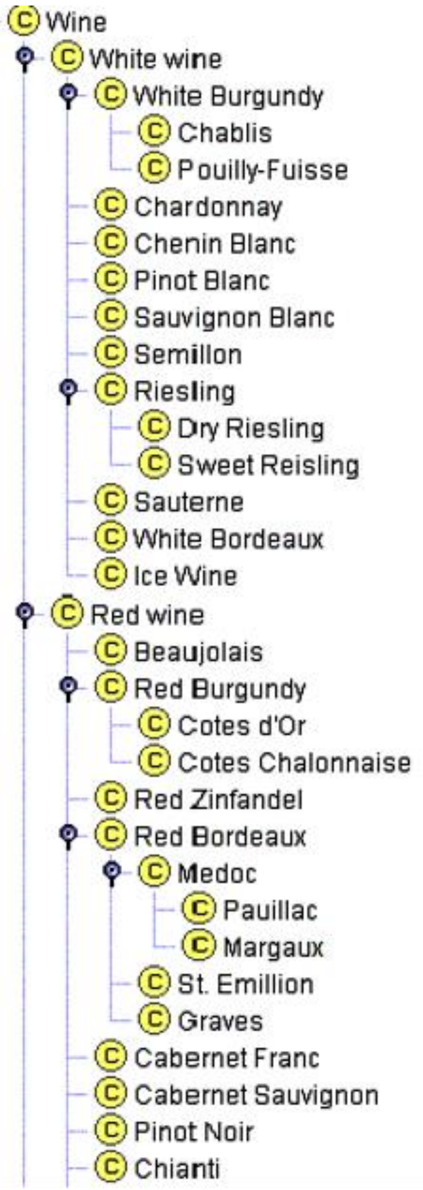
- Representing tokens of one type as tokens of another type



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(C) A set of wine bottles

(C) Case of wine

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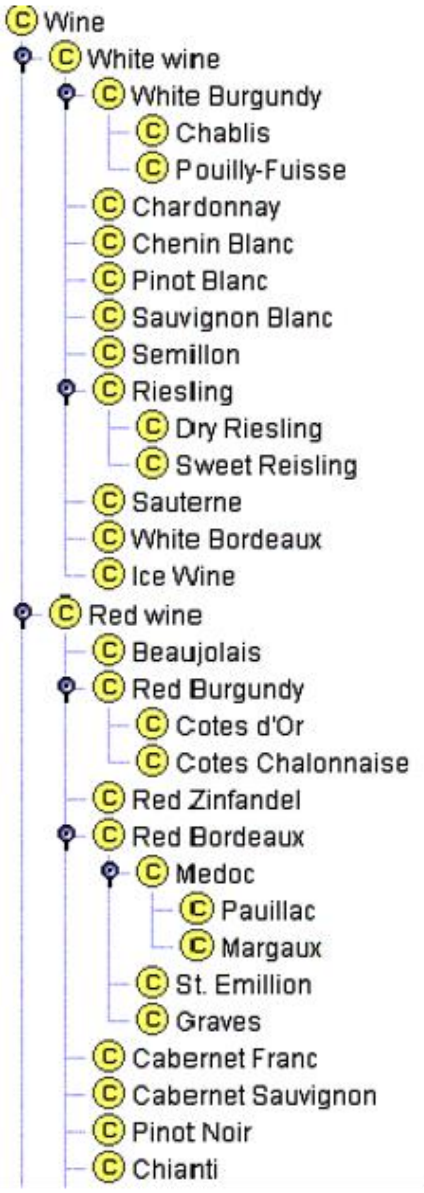

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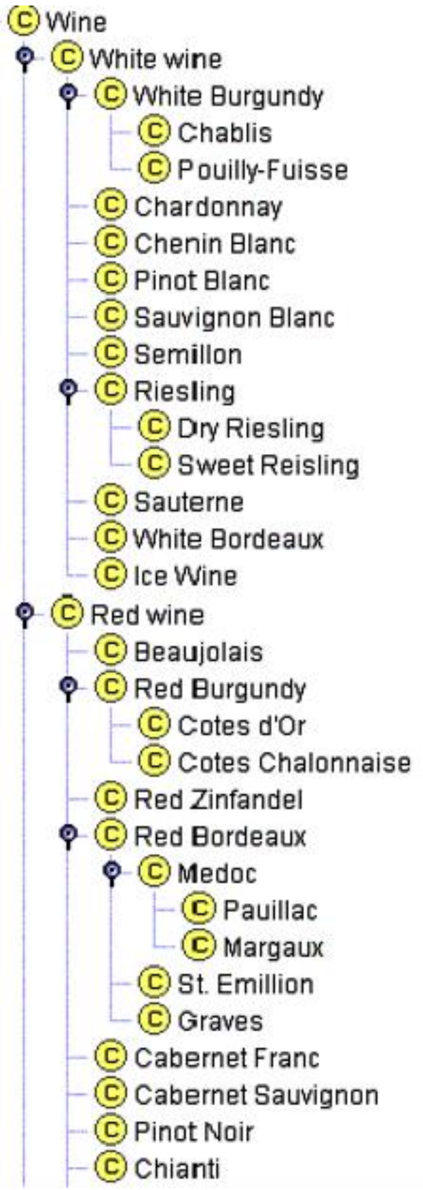

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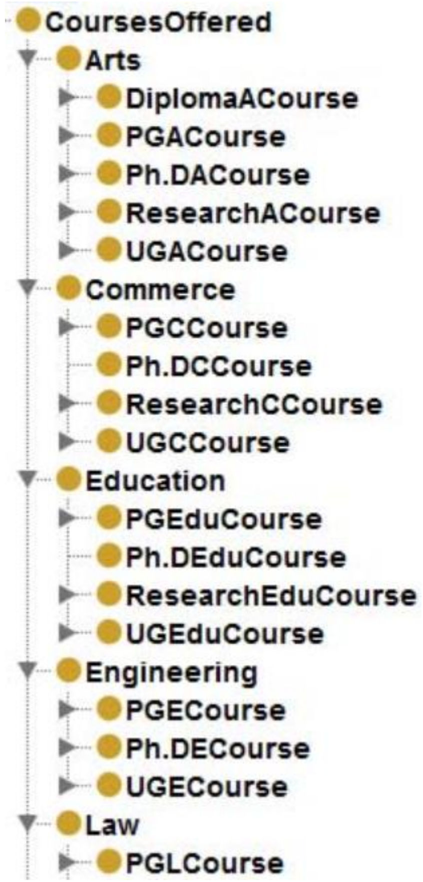

- CoursesOffered
  - Arts
    - DiplomaACourse
    - PGACourse
    - Ph.DACourse
    - ResearchACourse
    - UGACourse
  - Commerce
    - PGCCourse
    - Ph.DCCourse
    - ResearchCCourse
    - UGCCourse
  - Education
    - PGEduCourse
    - Ph.DEduCourse
    - ResearchEduCourse
    - UGEduCourse
  - Engineering
    - PGECourse
    - Ph.DECourse
    - UGECourse
  - Law
    - PGLCourse

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Agent requirements: unpacking Searle's view

- V0
  - Internal states are casually reducible to brain states
  - Internal states are ontologically irreducible to brain states

Phenomena of type A are ontologically reducible to phenomena of type B
if and only if A’s are nothing but B’s

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~~Phenomena of type A are ontologically reducible to phenomena of type B~~
~~if and only if A's are nothing but B's~~

Instances of class A are ontologically reducible to instances of class B
if and only if instances of A's are nothing but instances B's

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Agent requirements: unpacking Searle's view

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Phenomena of type A are causally reducible to phenomena of type B if and only if:

- the behavior of A’s are entirely casually explained by the behavior of B’s
- A’s have no causal powers in addition to the powers of B’s

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~~Phenomena of type A are causally reducible to phenomena of type B if and only if:~~

- ~~the behavior of A's are entirely casually explained by the behavior of B's~~
- ~~A's have no causal powers in addition to the powers of B's~~

Instances of class A are causally reducible to objects of class B if and only if:

- the behavior of instances of A's are entirely casually explained by the behavior of instances of B's
- instances of A's have no causal powers in addition to the powers of the instances of B's

Agent requirements, V0

- Internal states are casually reducible to brain states
- Internal states are ontologically irreducible to brain states

Design, V0

- Design decisions

Design, V0

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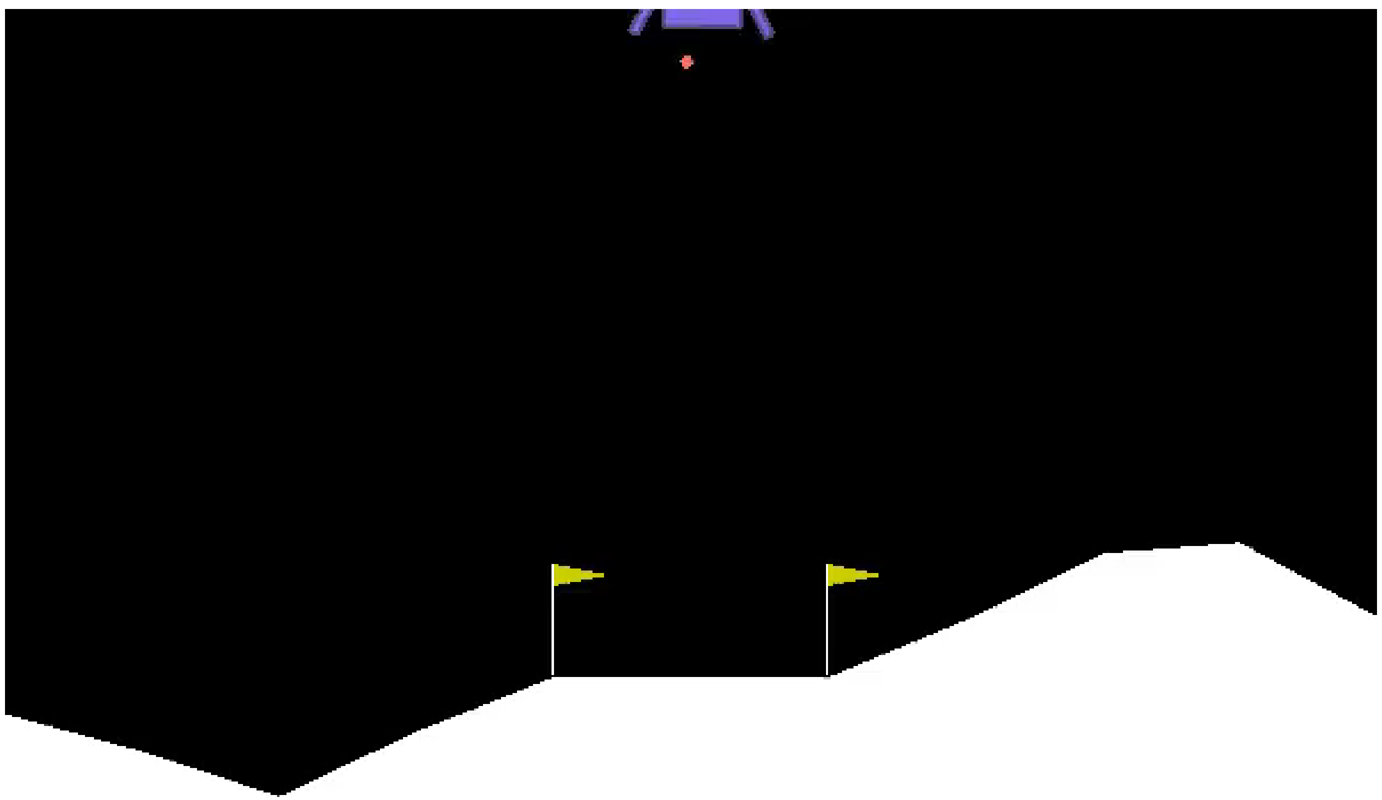
  - Environment and the agent’s “physical” form

Design, V0

- OpenAI's LunarLander-v2



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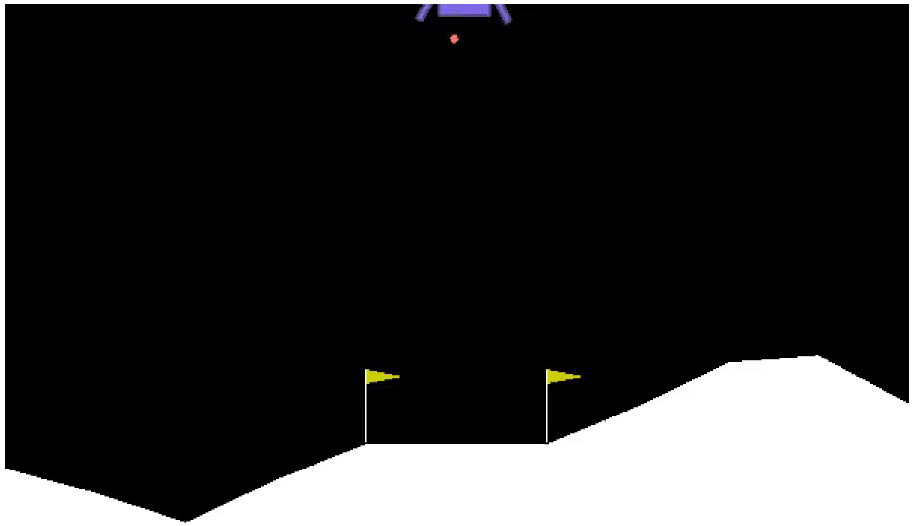
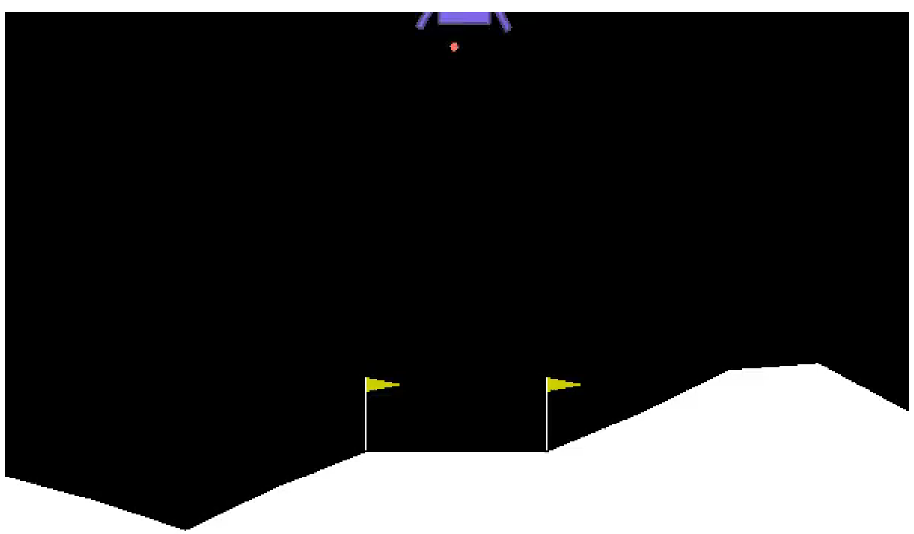
- Design decisions
  - Environment and the agent’s “physical” form



Design, V0

- Design decisions
  - Environment and the agent's "physical" form
  - Internal state of the agent



Design, V0

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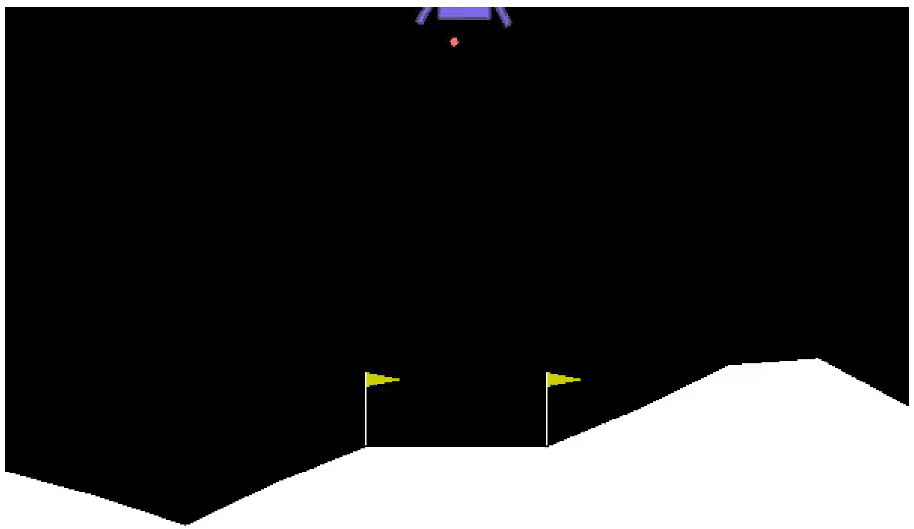
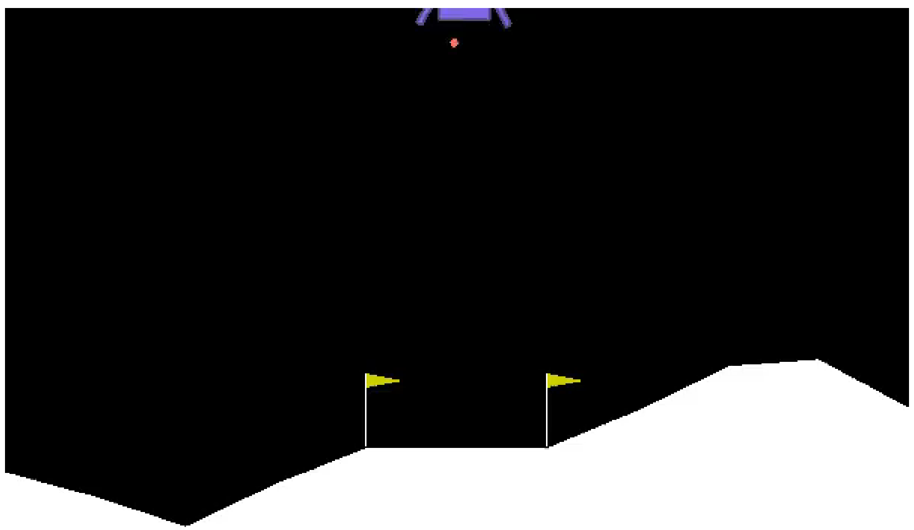
  - Environment and the agent’s “physical” form
  - Internal state of the agent
    - Beliefs about itself relative to semantically important regions

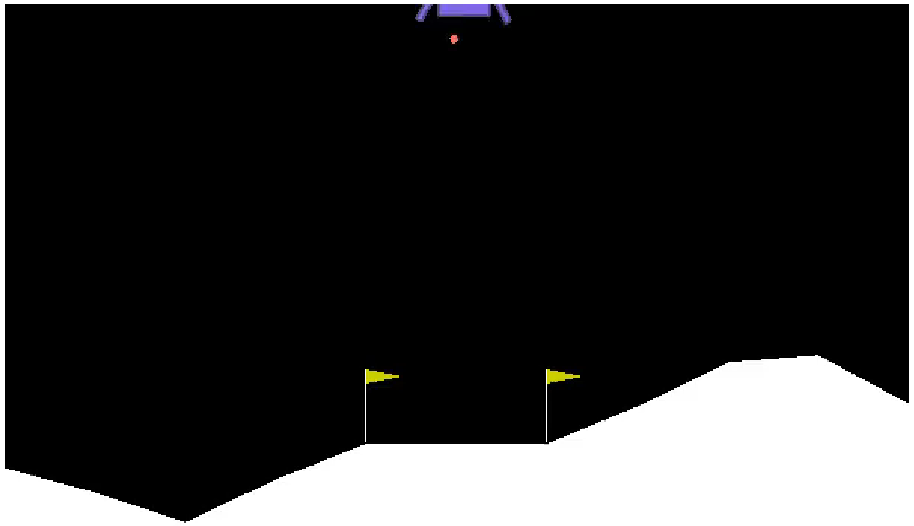


Design, V0



- Design decisions
  - Environment and the agent’s “physical” form
  - Internal state of the agent
    - Beliefs about itself relative to semantically important regions
      - Left of the flags, right of the flags, high above the ground, close to the ground, falling too fast

Design, V0



- Design decisions
  - Environment and the agent’s “physical” form
  - Internal state of the agent
    - Beliefs about itself relative to semantically important regions
      - Left of the flags, right of the flags, high above the ground, close to the ground, falling too fast
  - Brain state of the agent

Neural networks

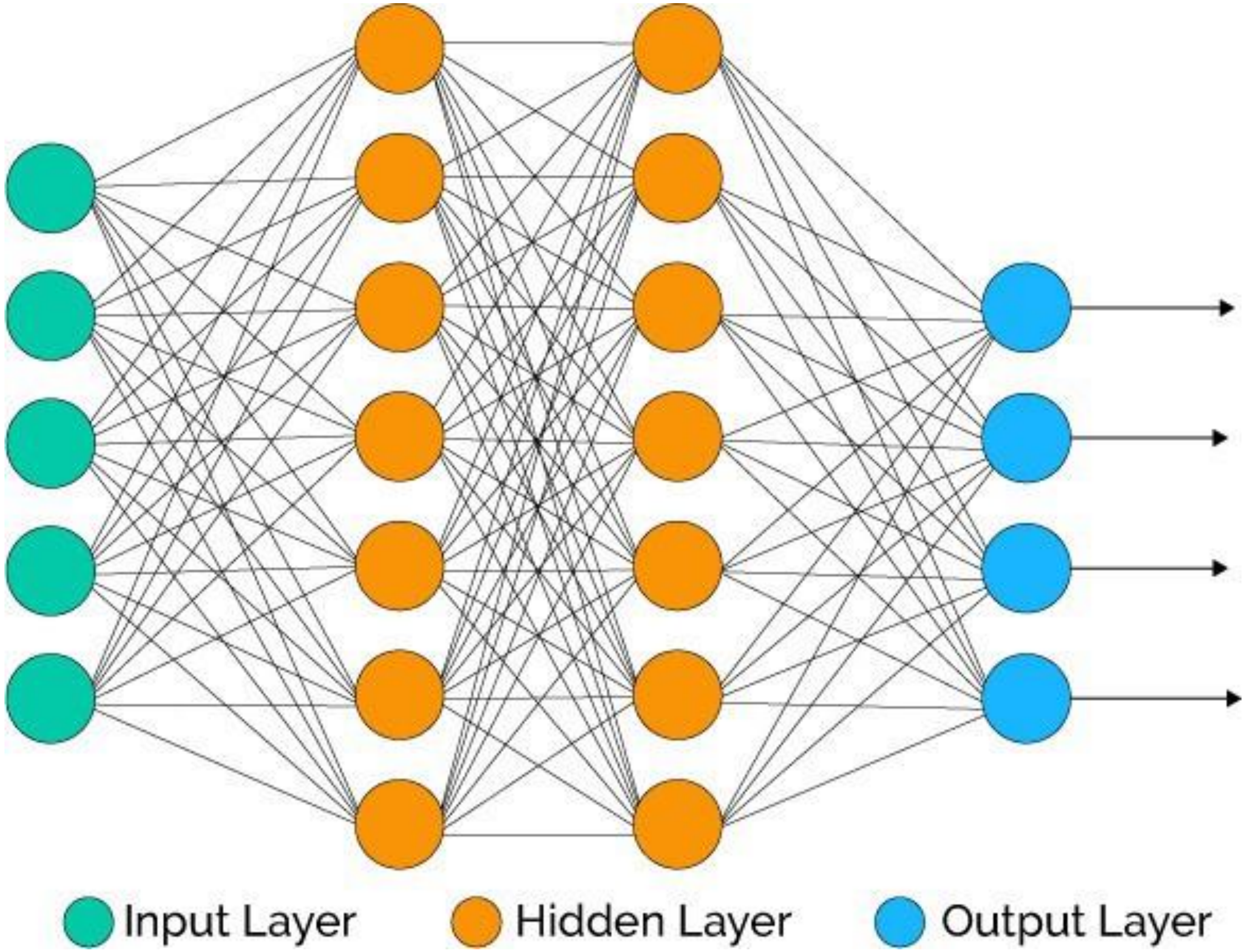


Image from:
https://medium.com/datadriveninvestor/when-not-to-use-neural-networks-89fb50622429

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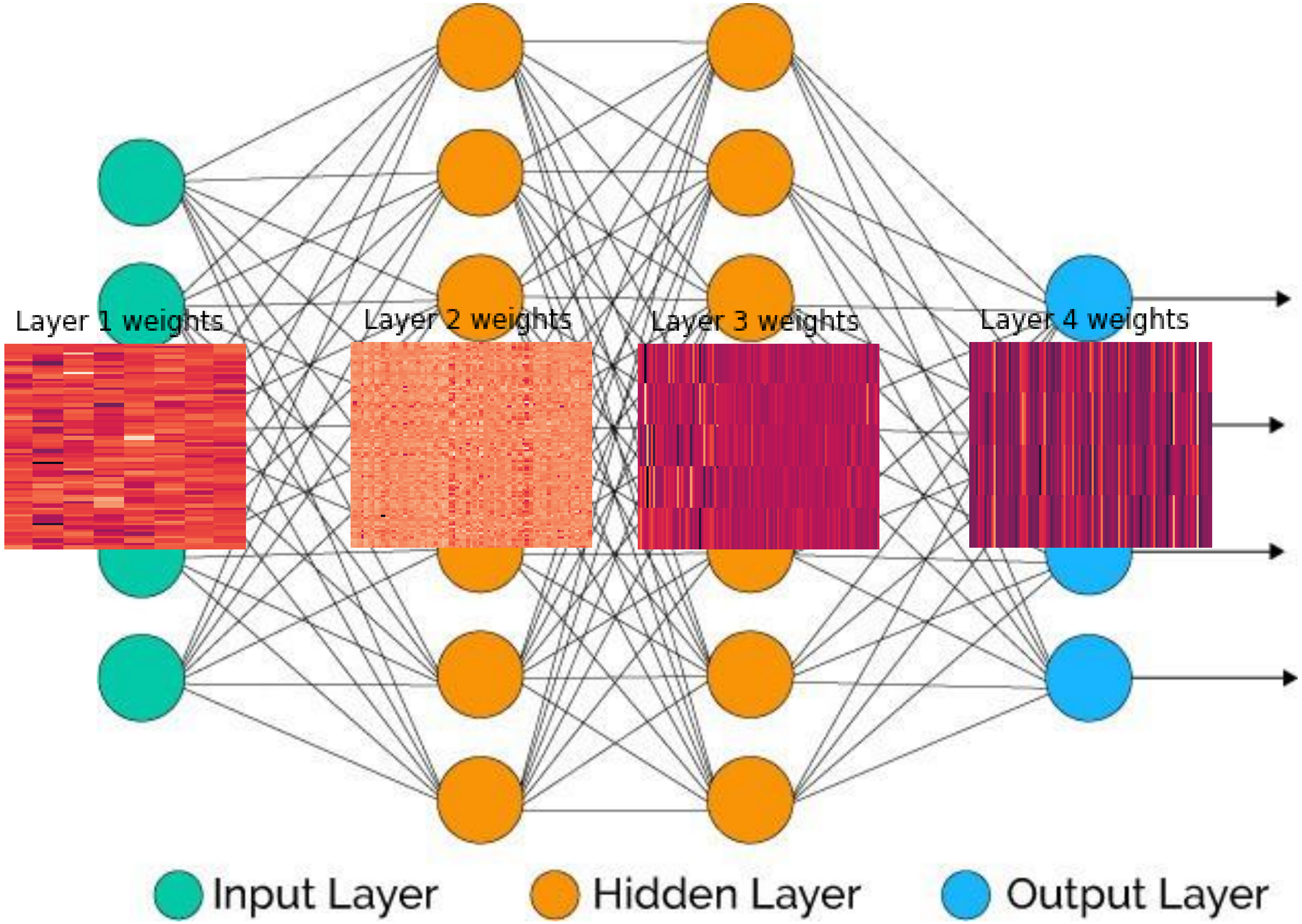

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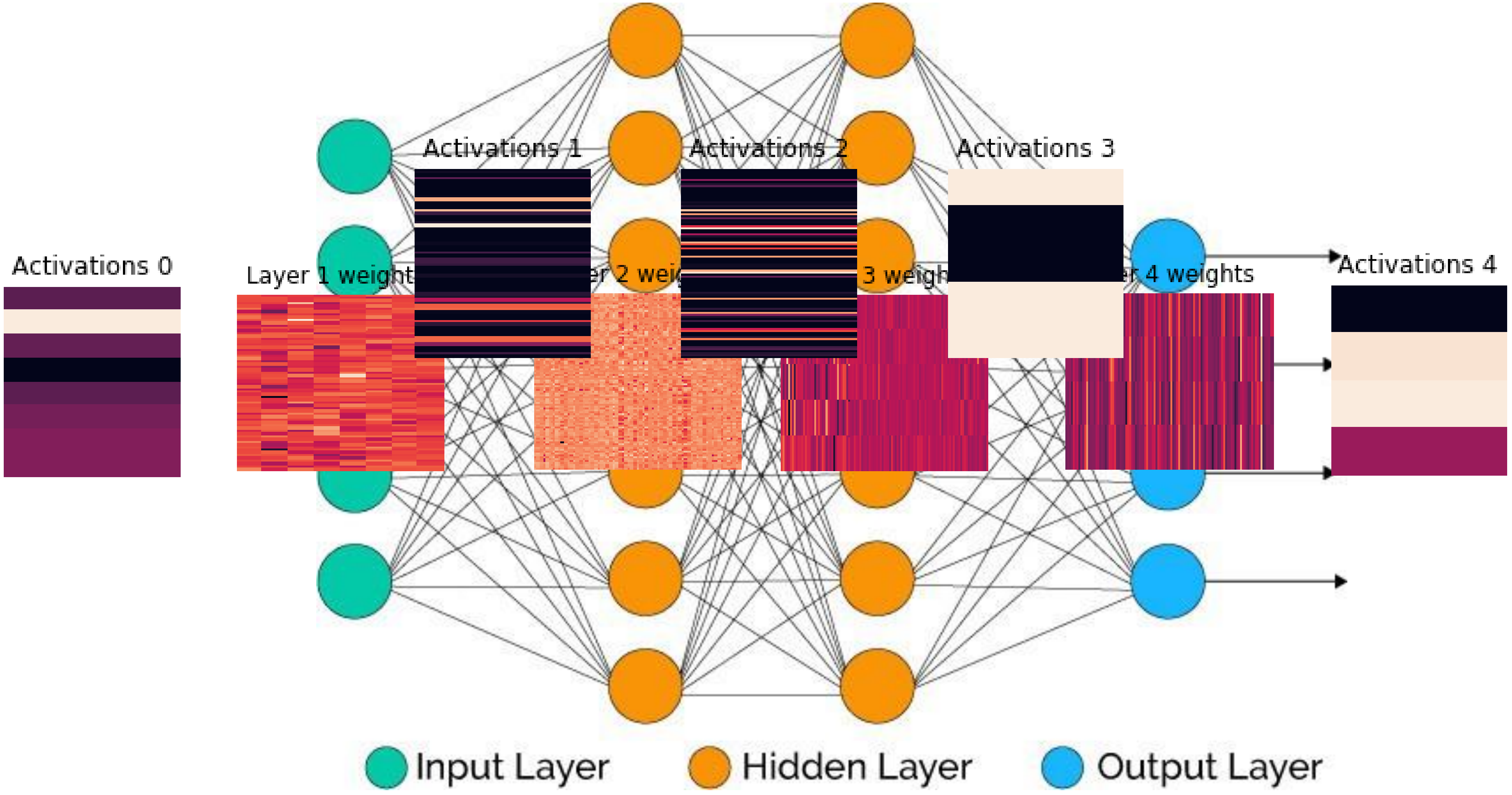

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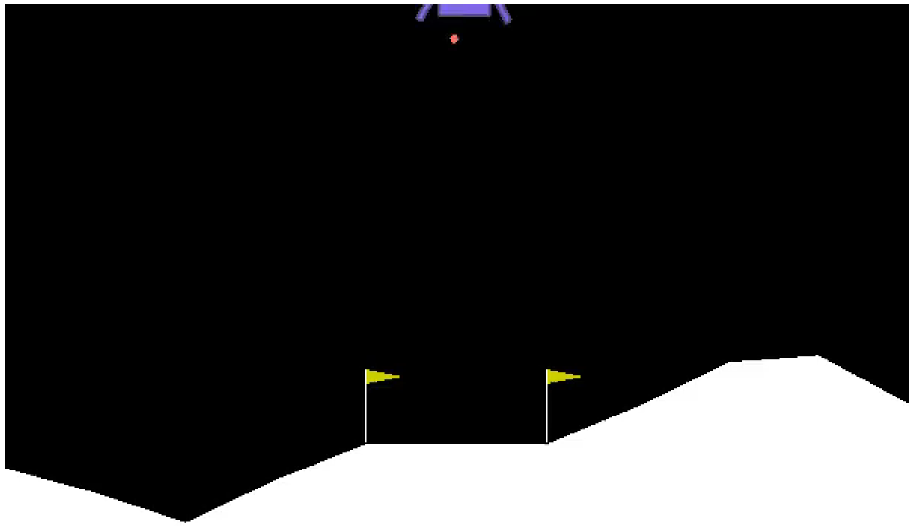
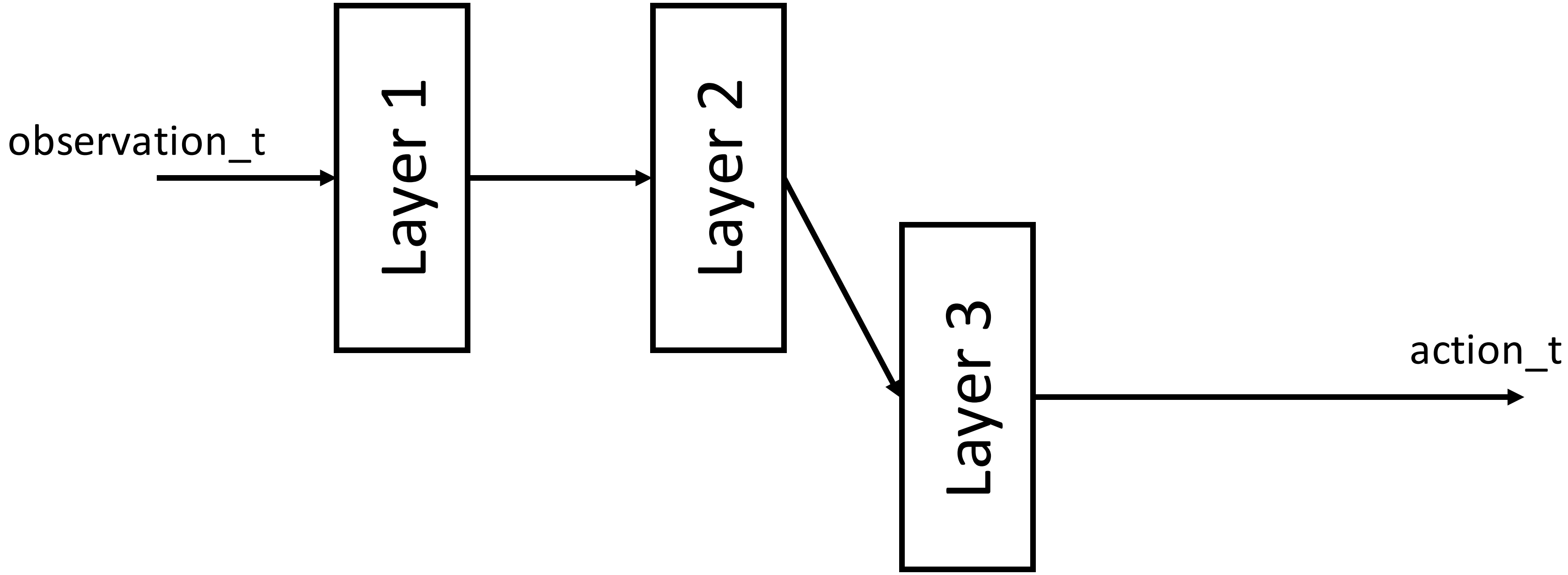
https://medium.com/datadriveninvestor/when-not-to-use-neural-networks-89fb50622429

Design, V0

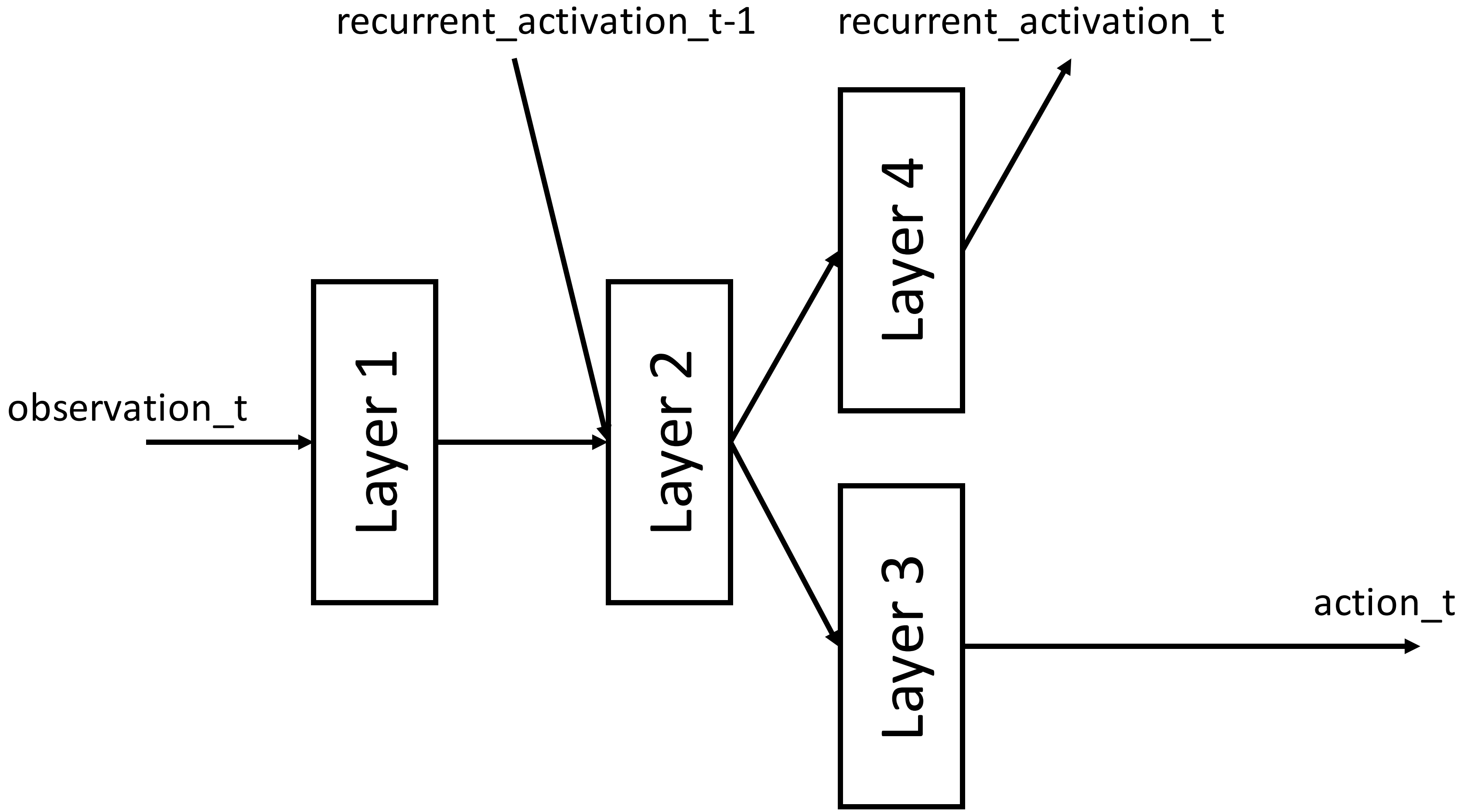


- Design decisions
  - Environment and the agent's "physical" form
  - Internal state of the agent
    - Beliefs about itself relative to semantically important regions
      - Left of the flags, right of the flags, high above the ground, close to the ground, falling too fast
  - Brain state of the agent

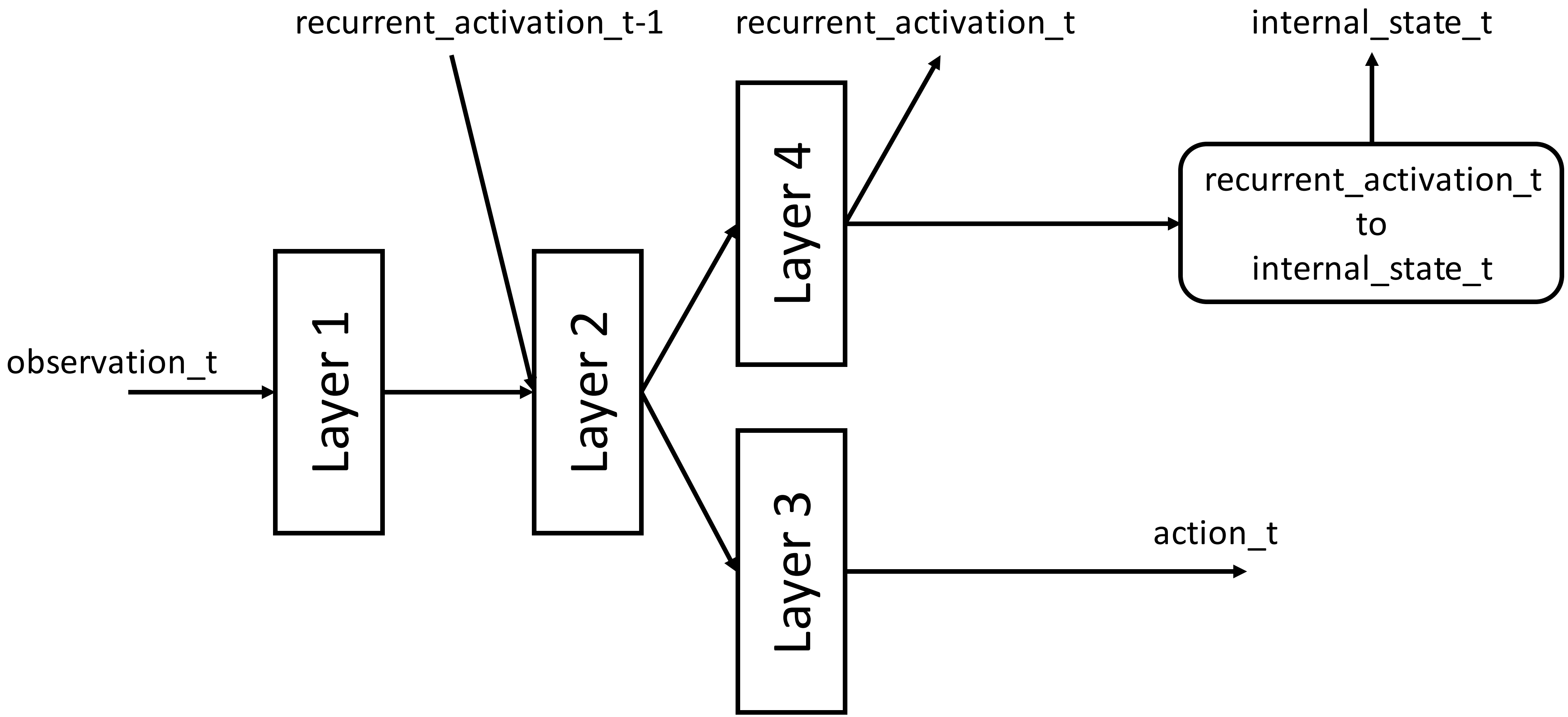
Design, V0



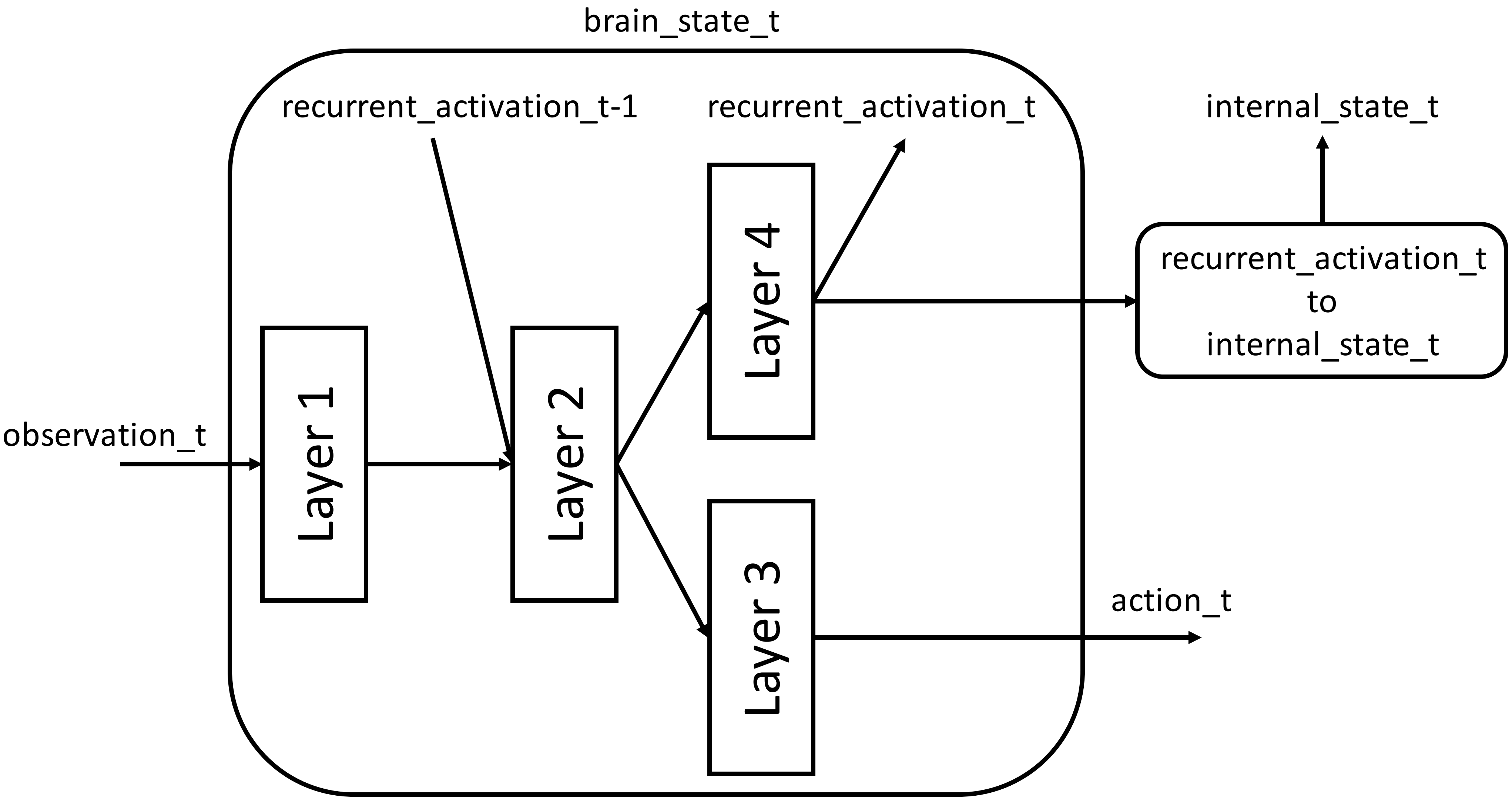
Design, V0


recurrent_activation_t-1
recurrent_activation_t
Layer 4
observation_t
Layer 1
Layer 2
Layer 3
action_t

Design, V0


recurrent_activation_t-1
recurrent_activation_t
internal_state_t
recurrent_activation_t
to
internal_state_t
observation_t
Layer 1
Layer 2
Layer 4
Layer 3
action_t

Design, V0



brain_state_t

recurrent_activation_t-1

recurrent_activation_t

internal_state_t

recurrent_activation_t
to
internal_state_t

observation_t

Layer 1

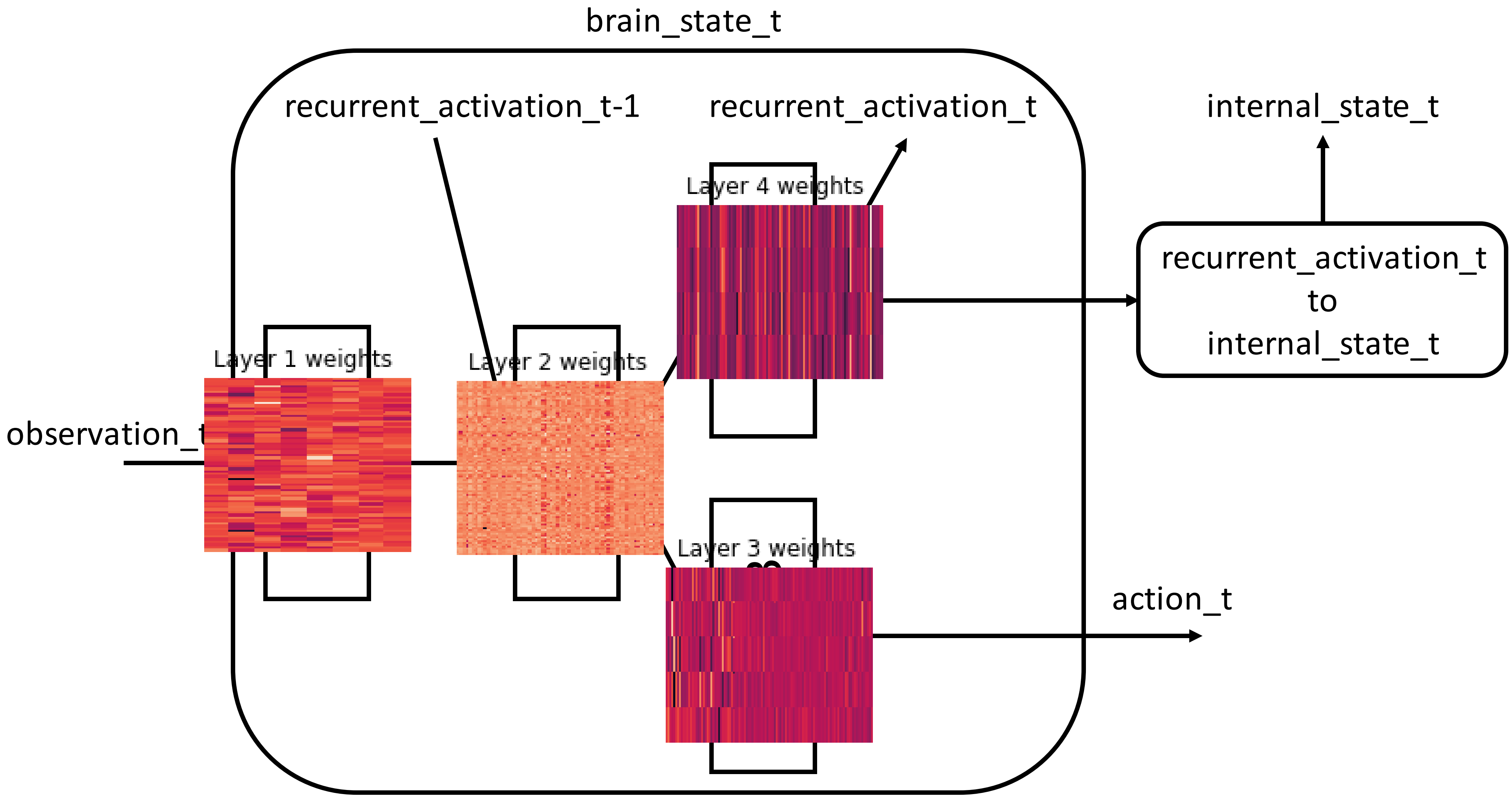
Layer 2

Layer 4

Layer 3

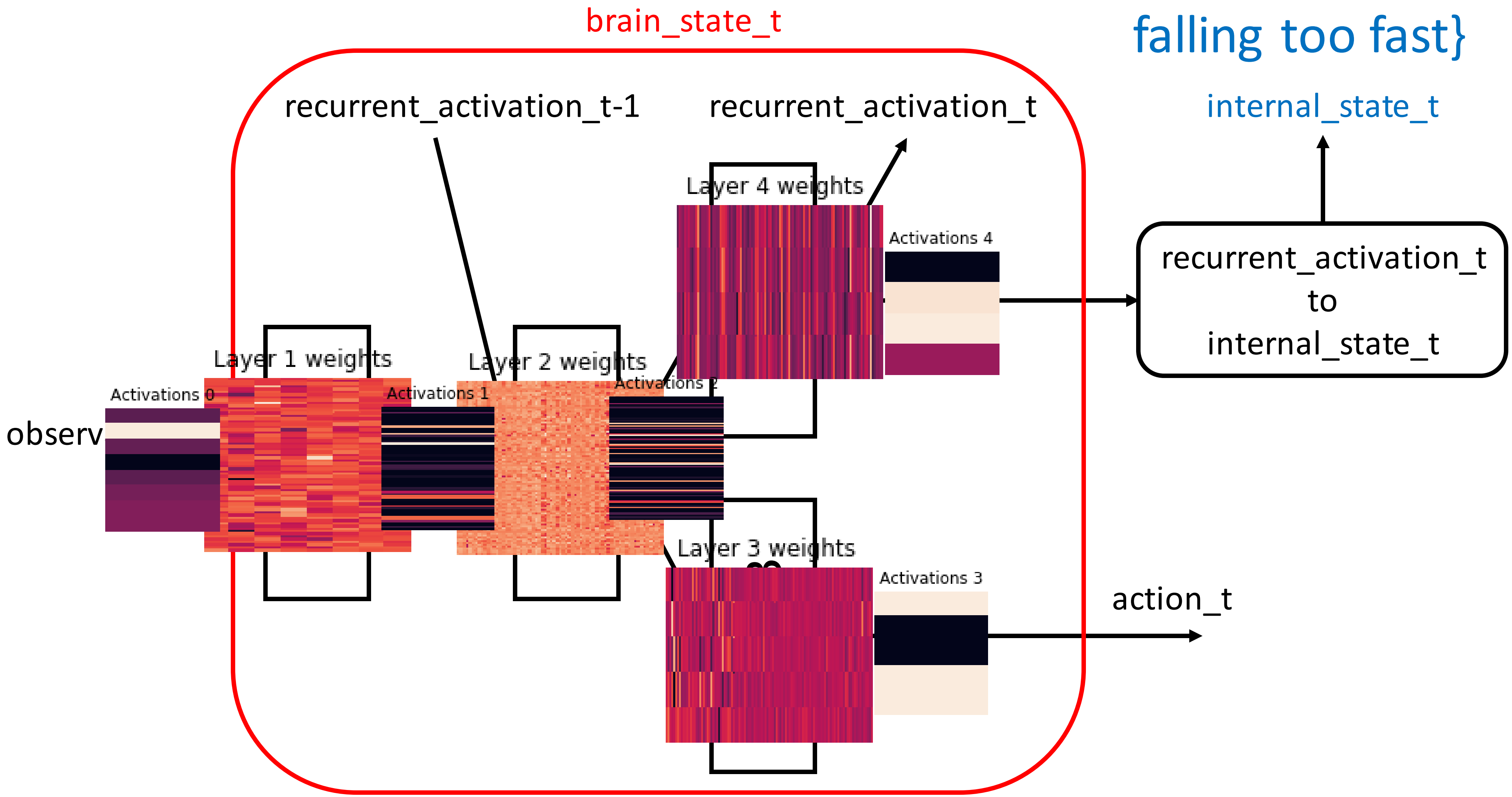
action_t

Design, V0


brain_state_t
recurrent_activation_t-1
recurrent_activation_t
internal_state_t
Layer 4 weights
recurrent_activation_t
to
internal_state_t
Layer 1 weights
Layer 2 weights
observation_t
Layer 3 weights
action_t

Design, V0

{Left of the flags,
high above the ground,
falling too fast}



brain_state_t

recurrent_activation_t-1

recurrent_activation_t

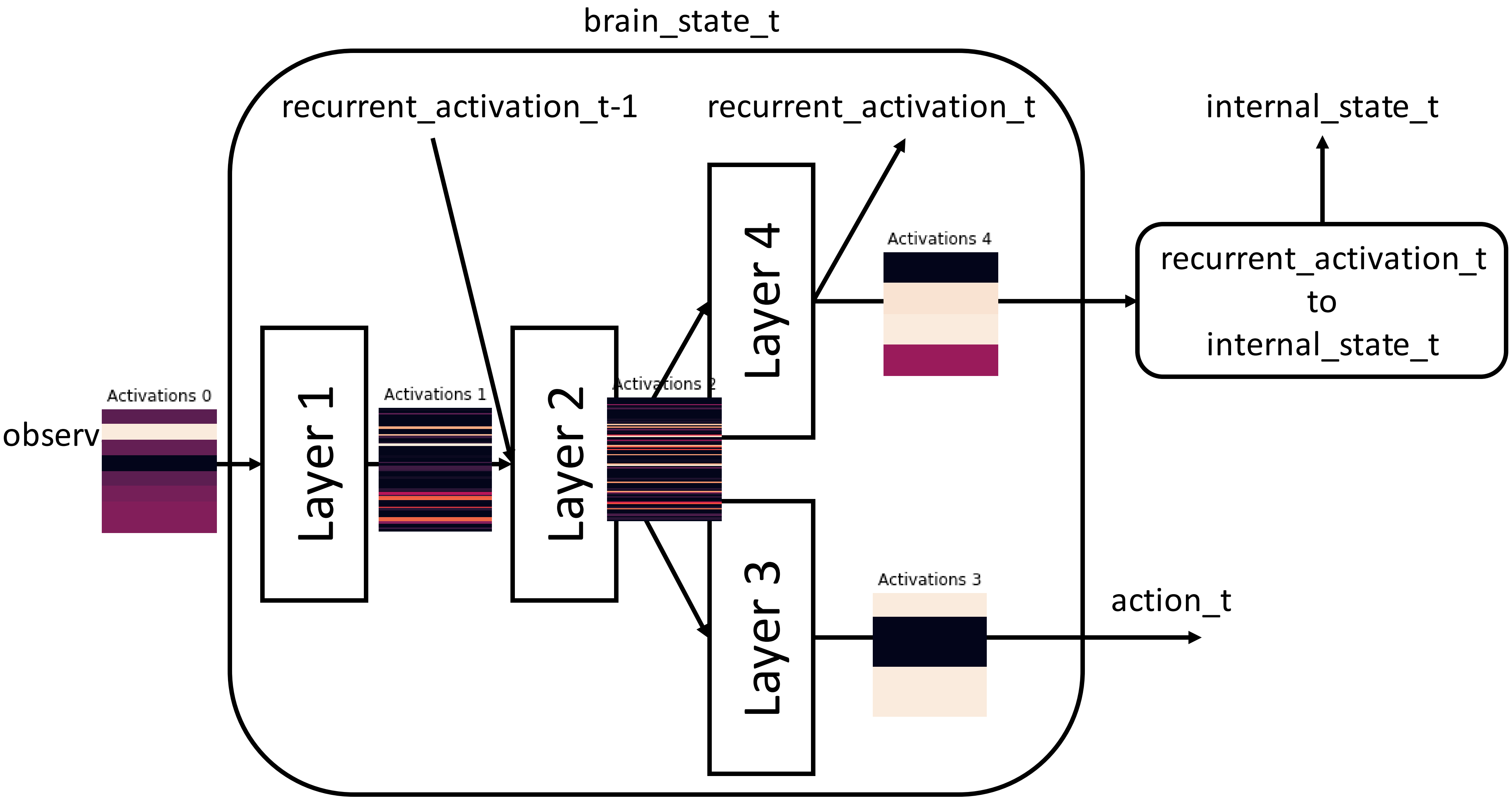
internal_state_t

recurrent_activation_t
to
internal_state_t

observ

action_t

Design, V0


brain_state_t
recurrent_activation_t-1
recurrent_activation_t
internal_state_t
recurrent_activation_t
to
internal_state_t
Activations 4
Layer 4
Activations 0
observ
Layer 1
Activations 1
Layer 2
Activations 2
Layer 3
Activations 3
action_t

Design, V0

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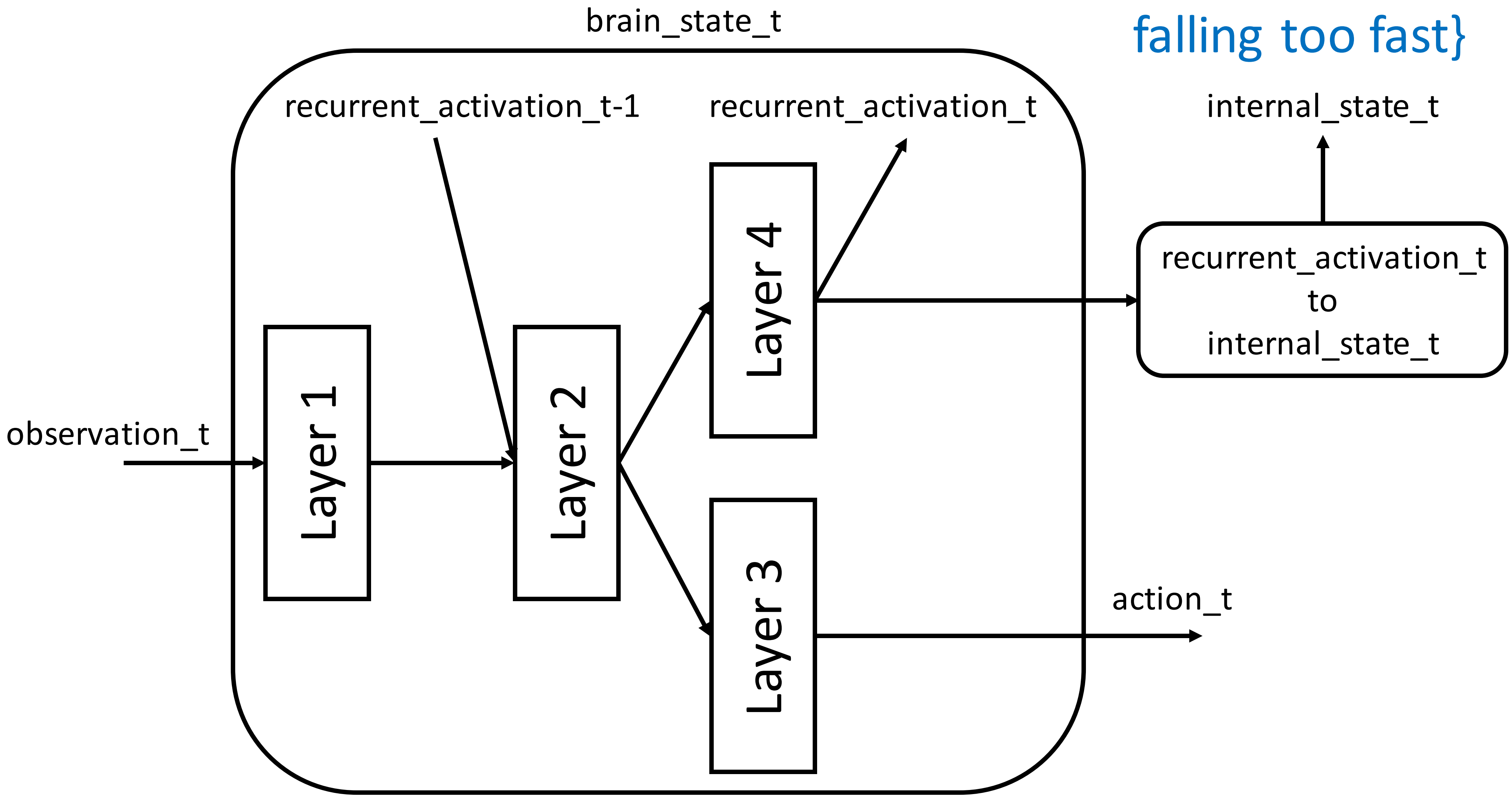

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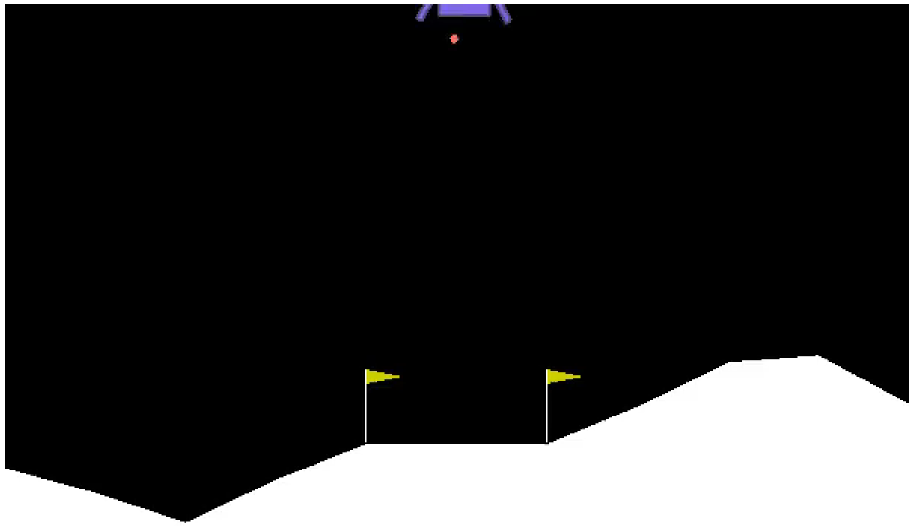

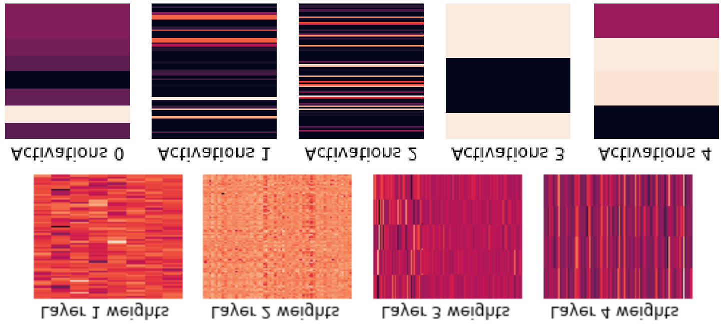

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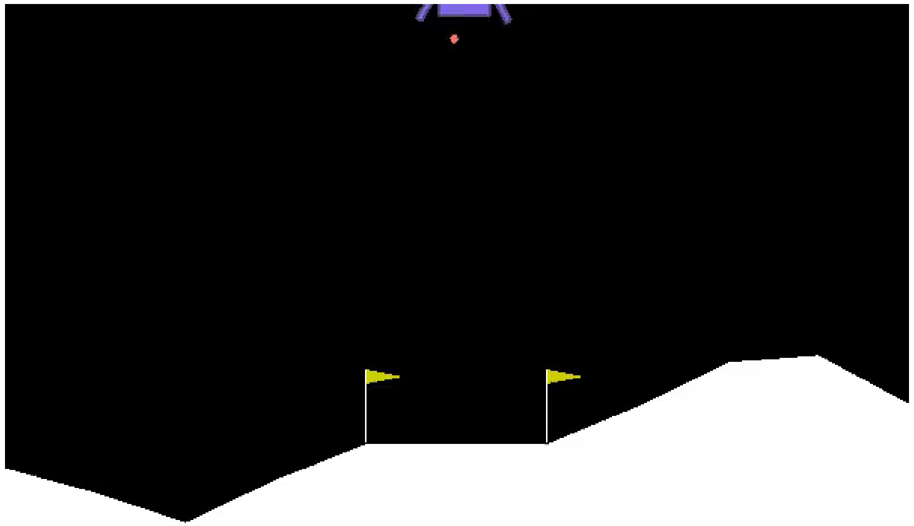

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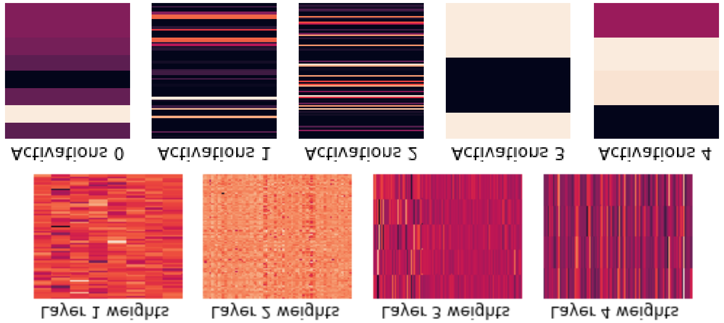
  - Brain state of the agent
  - Our ontology



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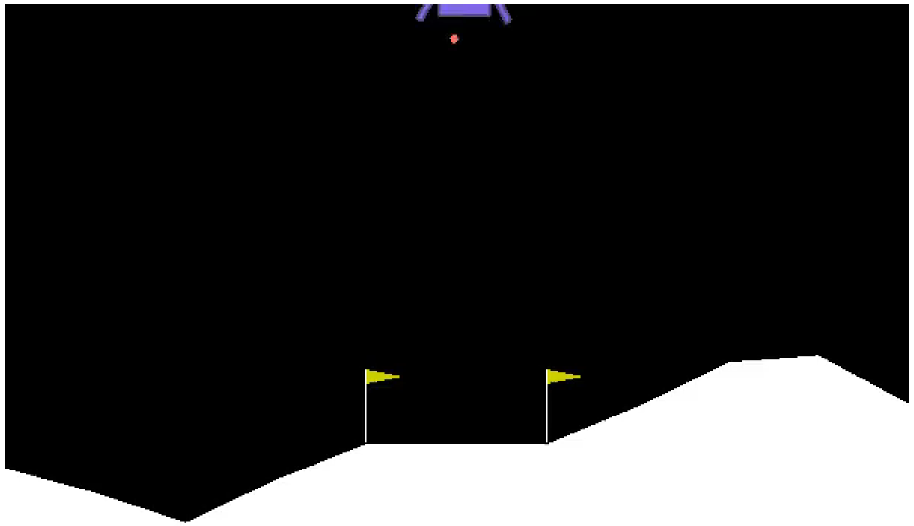

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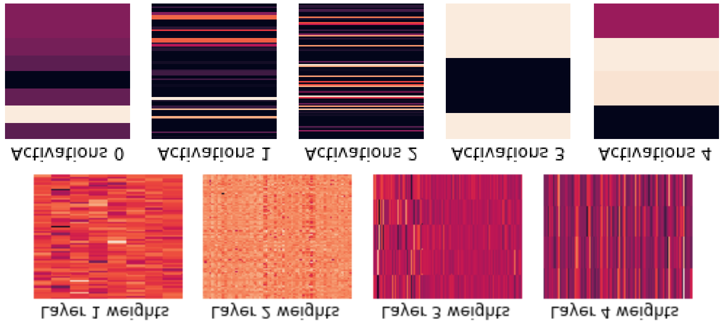
    - Beliefs about itself relative to semantically important regions
      - Left of the flags, right of the flags, high above the ground, close to the ground, falling too fast
  - Brain state of the agent
  - Our ontology
    - Layer weights of the neural network
    - Connectivity of the neural network
    - Activations of the neural network at time t
    - The agent's observation at time t
    - The agent's action at time t
    - The position and velocity of the agent at time t
    - Brain state (set of layer weights, activations, and connectivity) at time t
    - Region
    - Internal state (set of regions the agent believes it's in) at time t



Design, V0

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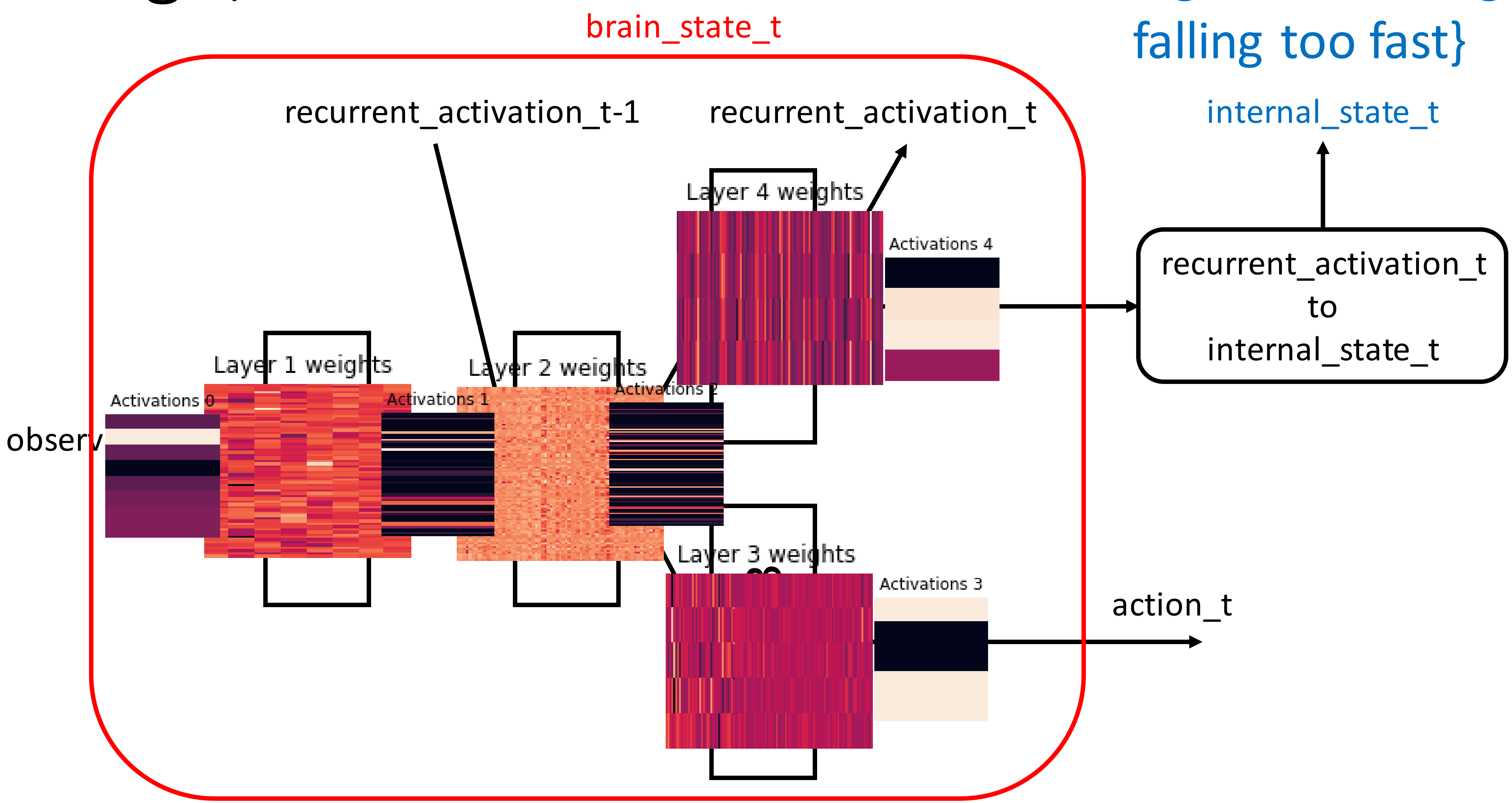


Design, V0

- Remaining questions
  - How will the agent learn to behave in the world?
  - How will brain states be “connected” to internal states?
  - How will the agent learn to recognize the correspondence between its internal states and its position/velocity?

Reinforcement learning

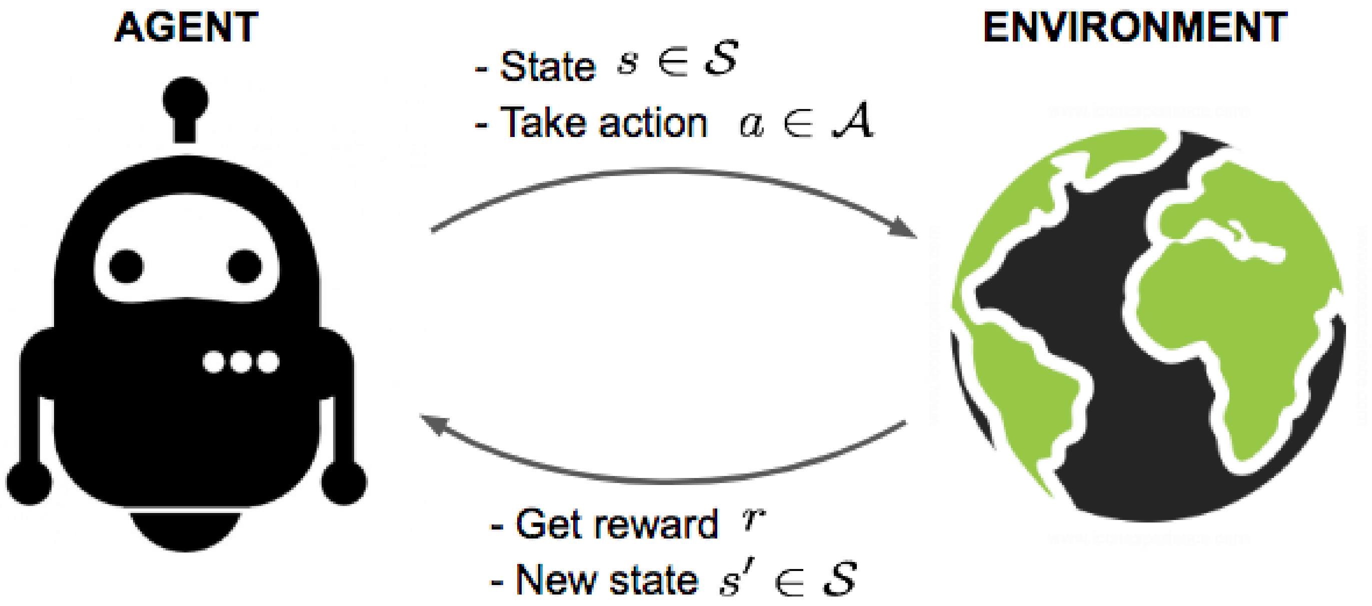
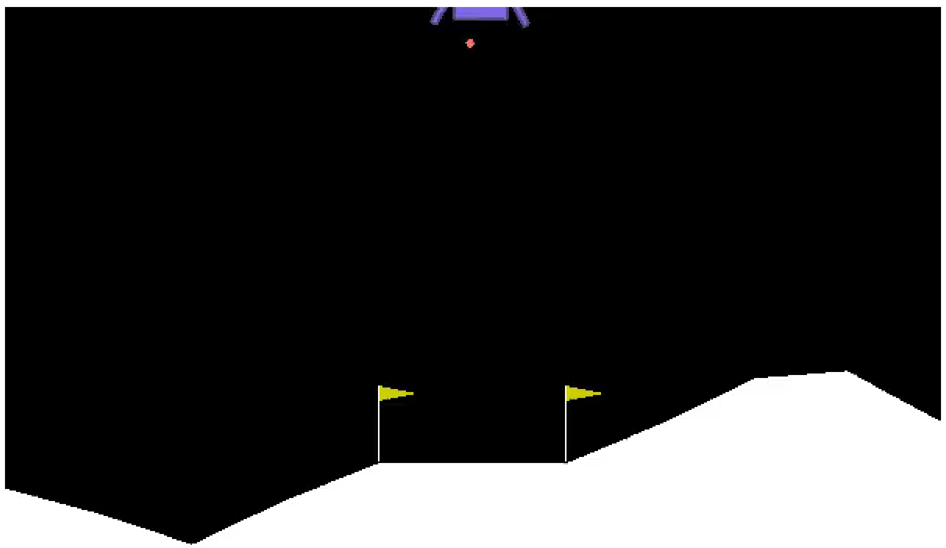

AGENT
ENVIRONMENT
- State $s \in \mathcal{S}$
- Take action $a \in \mathcal{A}$
- Get reward r
- New state $s' \in \mathcal{S}$

Image from:
https://lilianweng.github.io/lil-log/2018/02/19/a-long-peek-into-reinforcement-learning.html

Reinforcement learning

- OpenAI's LunarLander-v2
  - The goal is to softly land between the flags
  - Episode finishes if the lander crashes or comes to rest, receiving additional -100 or +100 points
  - Each leg ground contact is +10
  - Firing the engines is a small negative reward
  - Small positive reward for smoother flight
  - Fuel is infinite
  - Four discrete actions available:
    - do nothing, fire left orientation engine, fire main engine, fire right orientation engine
- We used DQN to train the network



Design, V0

- Remaining questions
    - How will the agent learn to behave in the world?
        - Reinforcement learning
    - How will brain states be “connected” to internal states?
    - How will the agent learn to recognize the correspondence between its internal states and its position/velocity?

Design, V0

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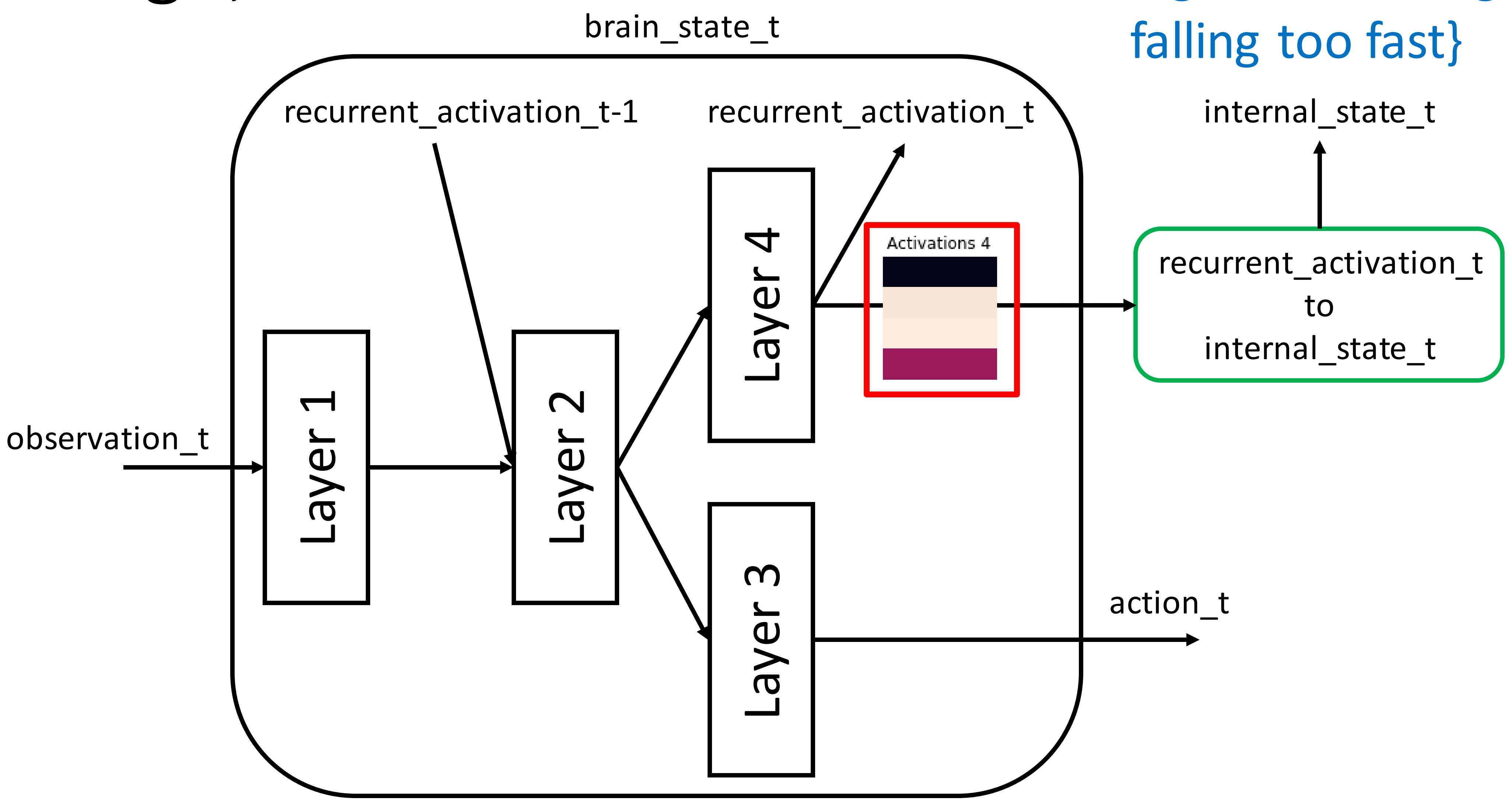


brain_state_t

recurrent_activation_t-1

recurrent_activation_t

internal_state_t

observation_t

Layer 1

Layer 2

Layer 4

Layer 3

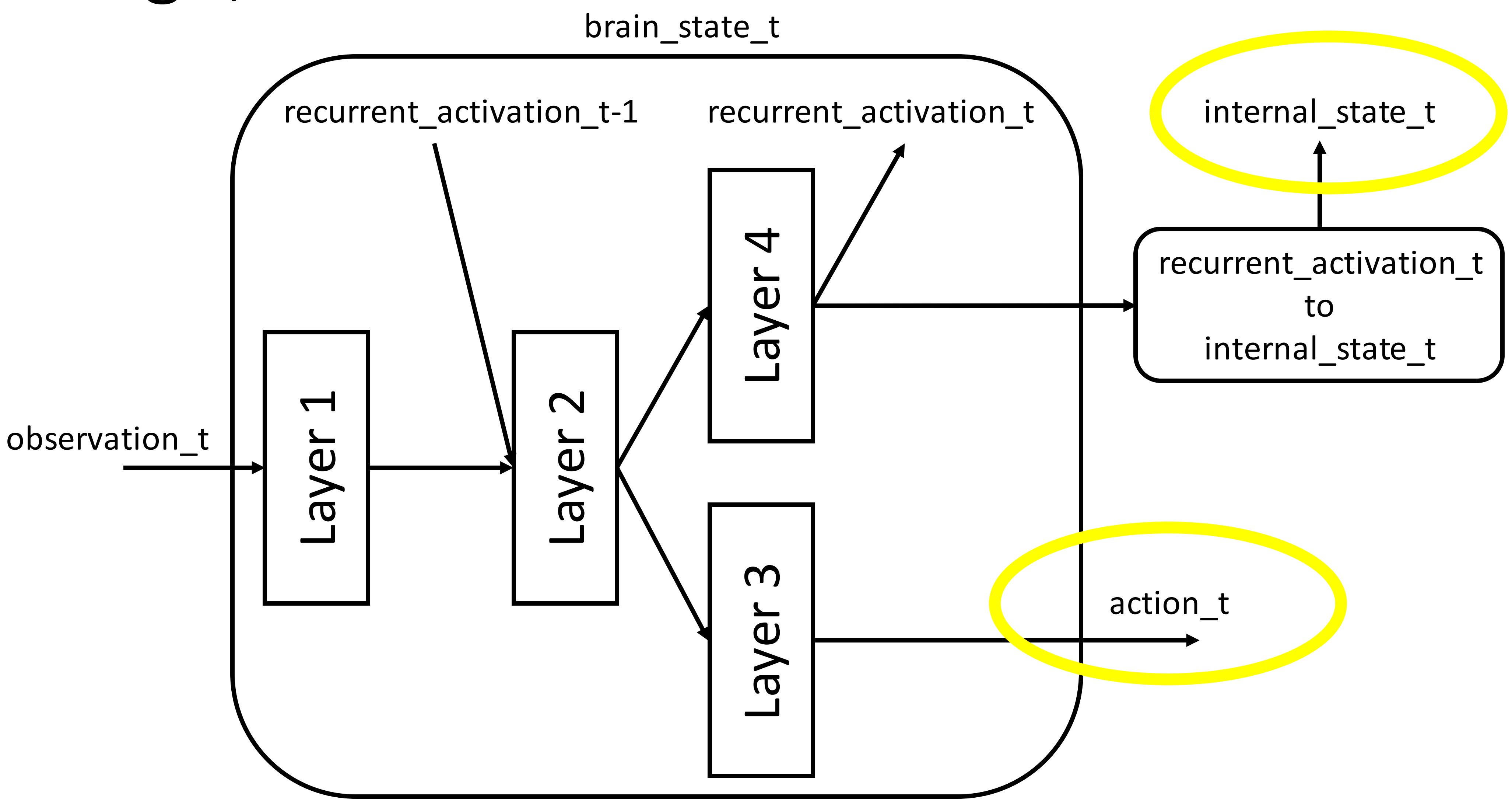
recurrent_activation_t
to
internal_state_t

action_t

Design, V0

- Remaining questions
    - How will the agent learn to behave in the world?
        - Reinforcement learning
    - How will brain states be “connected” to internal states?
        - A function that converts between classes (types)
    - How will the agent learn to recognize the correspondence between its internal states and its position/velocity?

Design, V0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Layer 1
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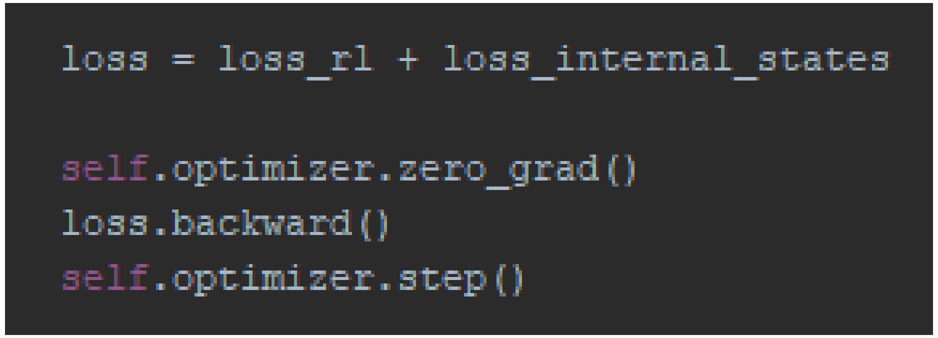
Layer 3
action_t

Design, V0

- Remaining questions
    - How will the agent learn to behave in the world?
        - Reinforcement learning
    - How will brain states be “connected” to internal states?
        - A function that converts between types
    - How will the agent learn to recognize the correspondence between its internal states and its position/velocity?
        - Jointly optimize both the RL loss to act and the internal state labeling loss

Design, V0

- Remaining questions
  - How will the agent learn to behave in the world?
    - Reinforcement learning
  - How will brain states be “connected” to internal states?
    - A function that converts between types
  - How will the agent learn to recognize the correspondence between its internal states and its position/velocity?
    - Jointly optimize both the RL loss to act and the internal state labeling loss



```
loss = loss_rl + loss_internal_states

self.optimizer.zero_grad()
loss.backward()
self.optimizer.step()
```

Quick review before moving to implementation

- Requirements, V0
  - Internal states are casually reducible to brain states
  - Internal states are ontologically irreducible to brain states
- Design, V0
  - Environment and the agent’s “physical” form
  - Internal state of the agent (set of semantically important regions)
  - Brain state of the agent (neural network structure and activations)
  - Our ontology
  - Jointly optimize both the RL loss to act and the internal state labeling loss
  - Simple function to map recurrent_activation_t to internal_state_t

Implementation, V0

- Jupyter notebook time!

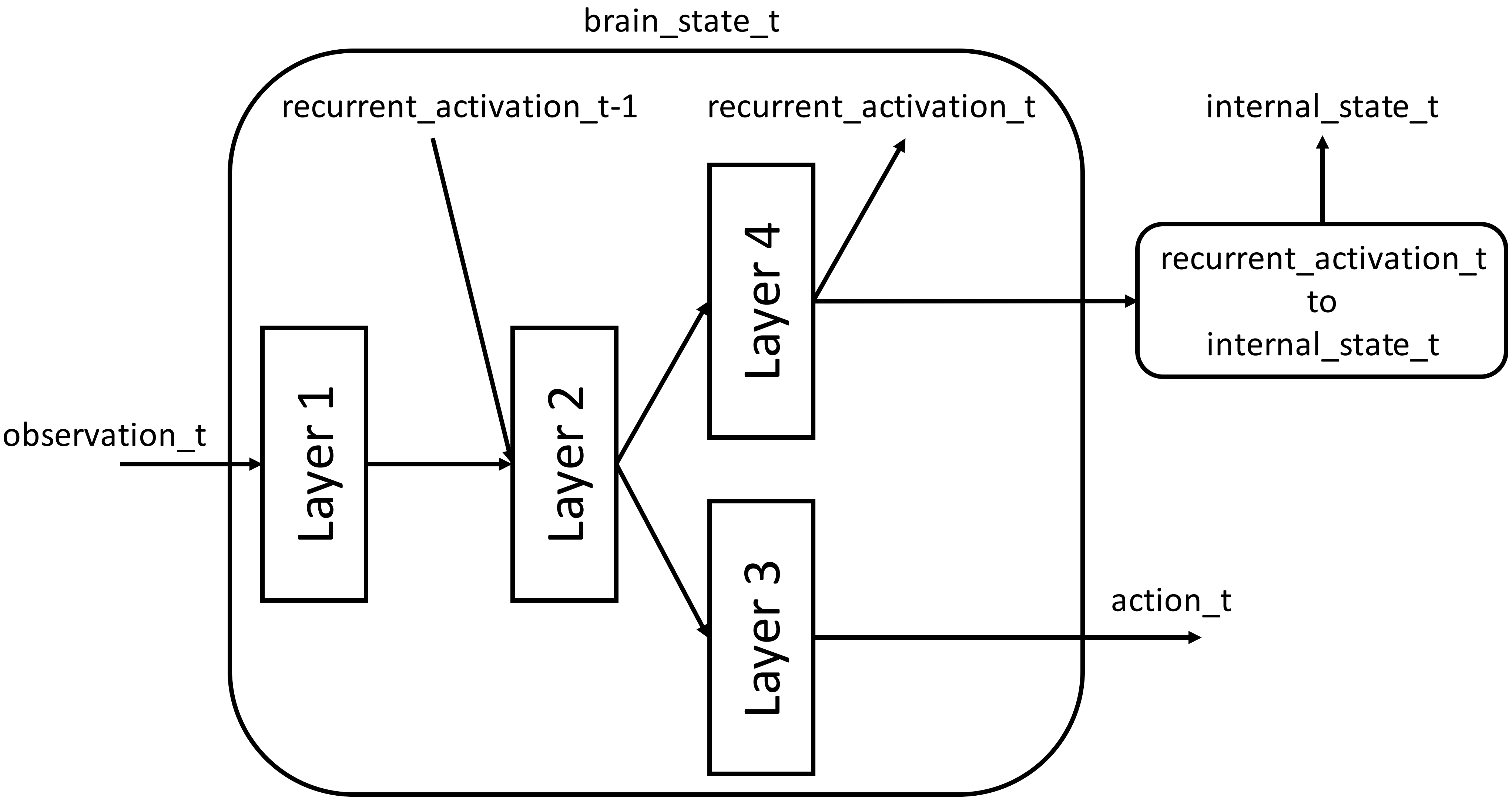
Conclusion

- Searle’s view
  - Consciousness is causally reducible to brain states
  - Consciousness is ontologically irreducible to brain states
- V2
  - Conscious mental states are casually reducible to brain states
  - Conscious mental states are ontologically irreducible to brain states
- V1
  - Mental states are casually reducible to brain states
  - Mental states are ontologically irreducible to brain states
- V0
  - Internal states are casually reducible to brain states
  - Internal states are ontologically irreducible to brain states

Conclusion

- Download and play with the code yourself
- github.com/Josh-Joseph/tsc-2019
- Disagree with our implementation of (a simplified version of) Searle's view?
    - Great! Open an issue and/or submit a pull request in GitHub
    - Concrete, constructive way of disagreeing
- Thoughts on other theories of mind/consciousness that may be particularly well suited for this type of approach?

Backup slides


brain_state_t
recurrent_activation_t-1
recurrent_activation_t
internal_state_t
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Layer 1
Layer 2
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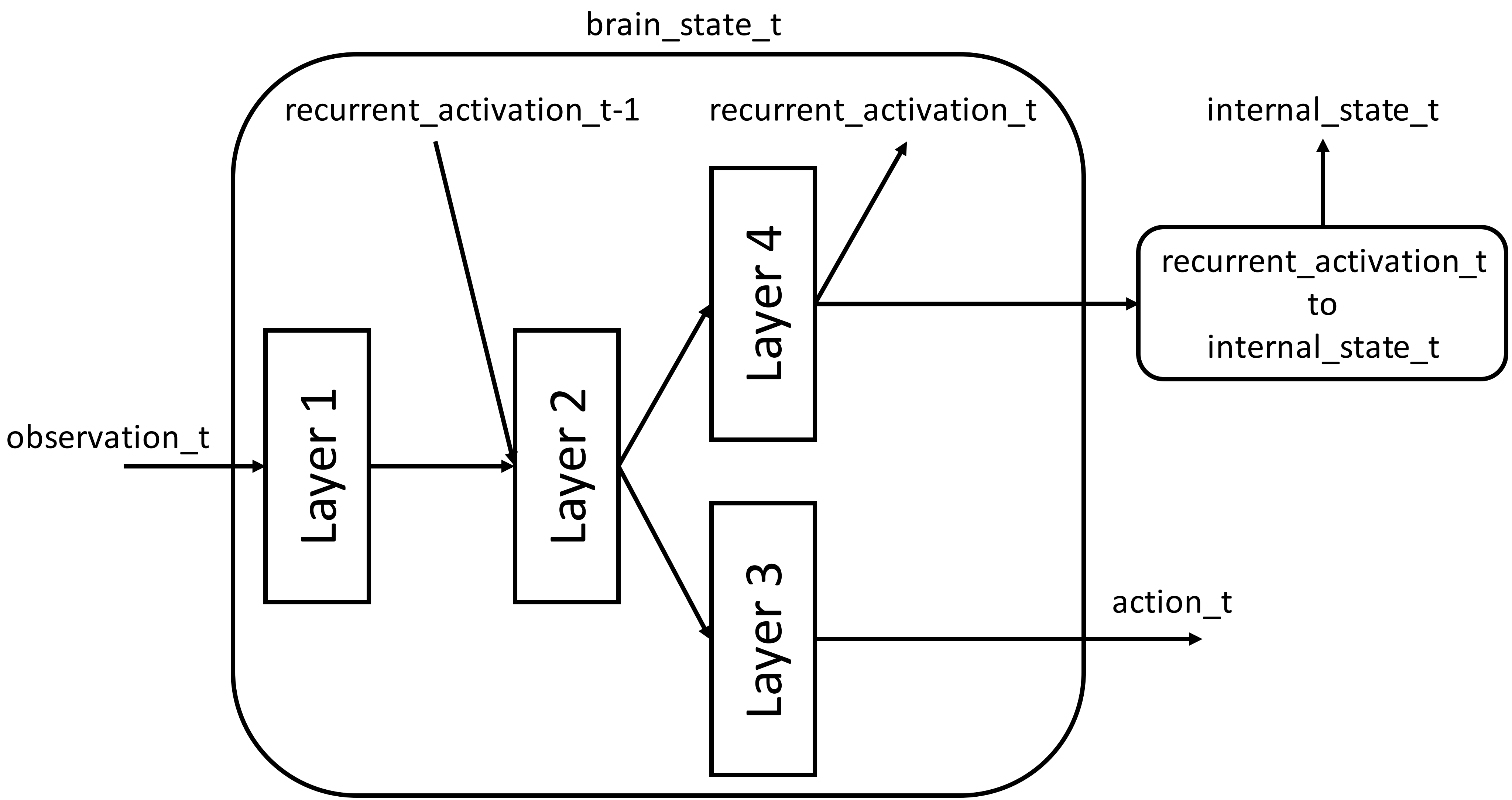
Layer 3
recurrent_activation_t
to
internal_state_t
action_t



brain_state_t
recurrent_activation_t-1
recurrent_activation_t
internal_state_t
Layer 4
recurrent_activation_t
to
internal_state_t
observation_t
Layer 1
Layer 2
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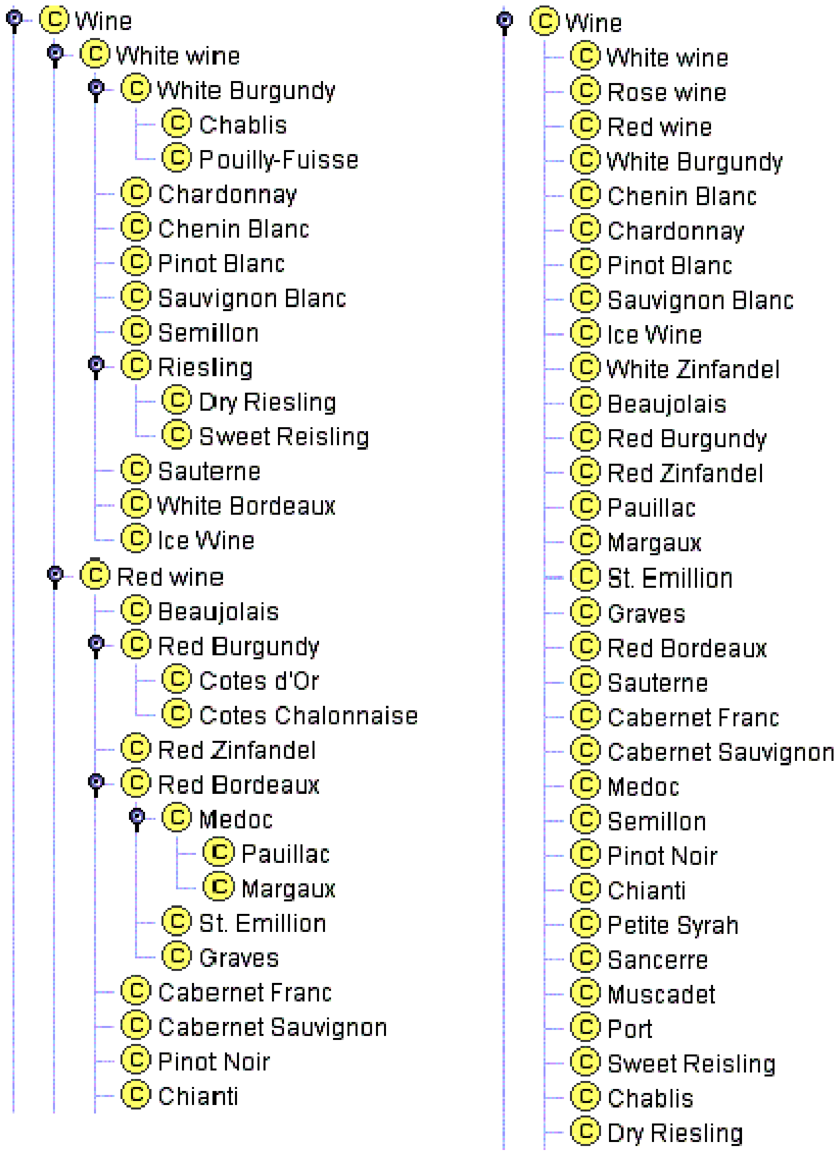
action_t

Background

- Reinforcement learning
- Neural networks
- Ontologies in computer science
  - "They drive the same car"
  - Type-token distinction
    - They drive the same car type (a Toyota)
    - They drive the same car token (the 2003 Toyota Carolla with VIN: 2QFBORHE4KP911561)



- Wine
  - White wine
    - White Burgundy
      - Chablis
      - Pouilly-Fuisse
    - Chardonnay
    - Chenin Blanc
    - Pinot Blanc
    - Sauvignon Blanc
    - Semillon
    - Riesling
      - Dry Riesling
      - Sweet Reisling
    - Sauterne
    - White Bordeaux
    - Ice Wine
  - Red wine
    - Beaujolais
    - Red Burgundy
      - Cotes d'Or
      - Cotes Chalonnaise
    - Red Zinfandel
    - Red Bordeaux
      - Medoc
        - Pauillac
        - Margaux
      - St. Emillion
      - Graves
    - Cabernet Franc
    - Cabernet Sauvignon
    - Pinot Noir
    - Chianti

- Wine
  - White wine
  - Rose wine
  - Red wine
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  - Sauvignon Blanc
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  - Chianti
  - Petite Syrah
  - Sancerre
  - Muscadet
  - Port
  - Sweet Reisling
  - Chablis
  - Dry Riesling

From https://protege.stanford.edu/publications/ontology_development/ontology101-noy-mcguinness.html

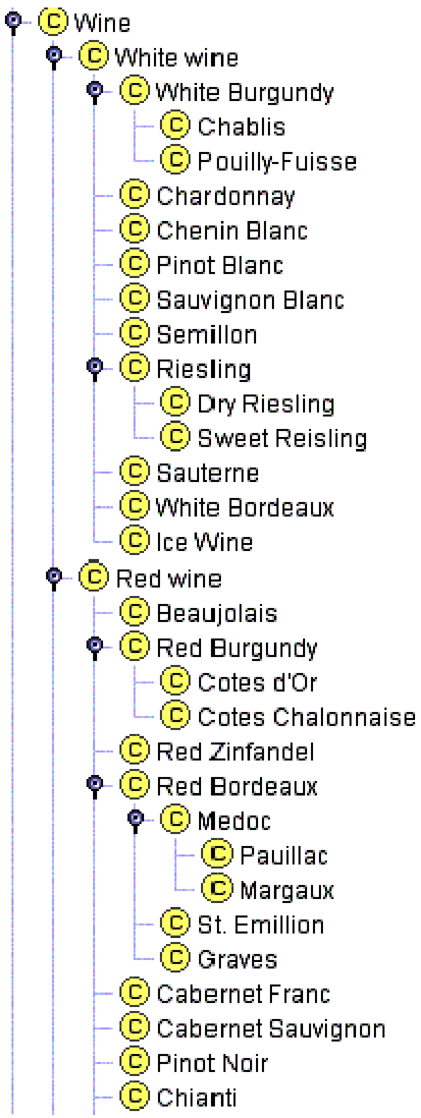
Agent requirements: unpacking Searle's view

- ~~Conscious~~ mental states are causally reducible to brain states but mental states are ontologically irreducible to brain states
- This has the feel of *maybe* being concrete enough that we can try to build an example of what we think Searle means

Unpacking Searle’s view

- ~~Conscious~~ mental states are causally reducible to brain states but mental states are ontologically irreducible to brain states
- This has the feel of *maybe* being concrete enough that we can try to build an example of what we think Searle means
- So let's build an agent who exhibits:
  - Mental states that are causally reducible to brain states
  - Mental states that are ontologically irreducible to brain states

Ontolog m cience



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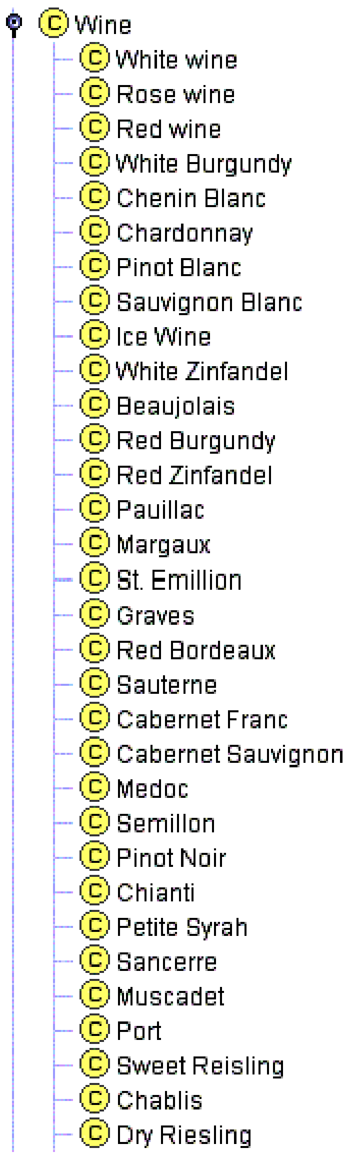

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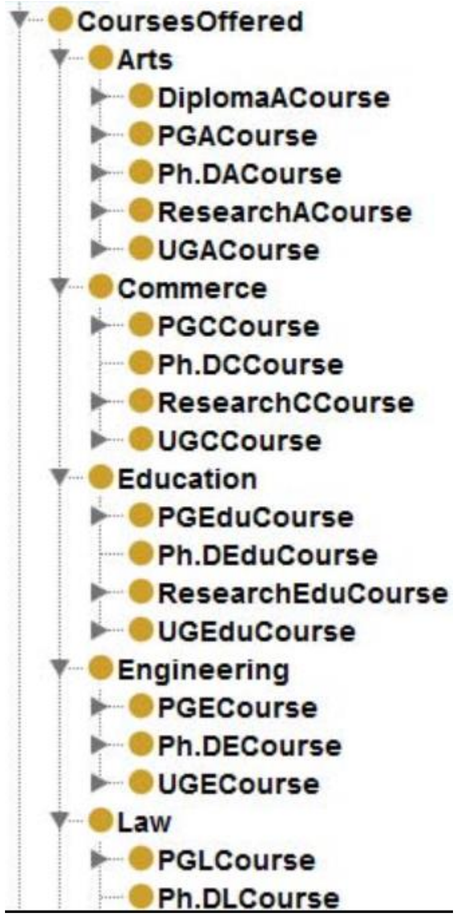

- CoursesOffered
  - Arts
    - DiplomaACourse
    - PGACourse
    - Ph.DACourse
    - ResearchACourse
    - UGACourse
  - Commerce
    - PGCCourse
    - Ph.DCCourse
    - ResearchCCourse
    - UGCCourse
  - Education
    - PGEduCourse
    - Ph.DEduCourse
    - ResearchEduCourse
    - UGEduCourse
  - Engineering
    - PGECourse
    - Ph.DECourse
    - UGECourse
  - Law
    - PGLCourse
    - Ph.DLCourse

Images from:
https://protege.stanford.edu/publications/ontology_development/ontology101-noy-mcguinness.html
https://www.researchgate.net/figure/Owl-Viz-view-of-course-ontology_fig1_261339041

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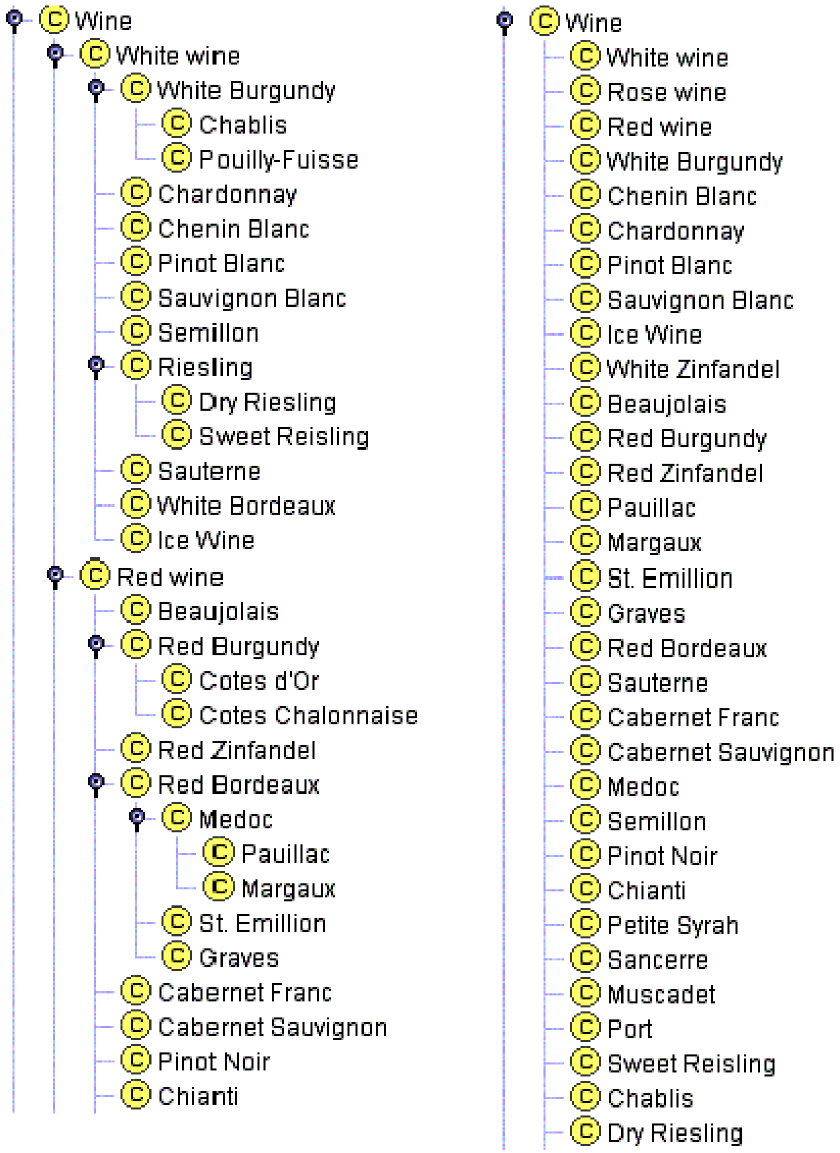

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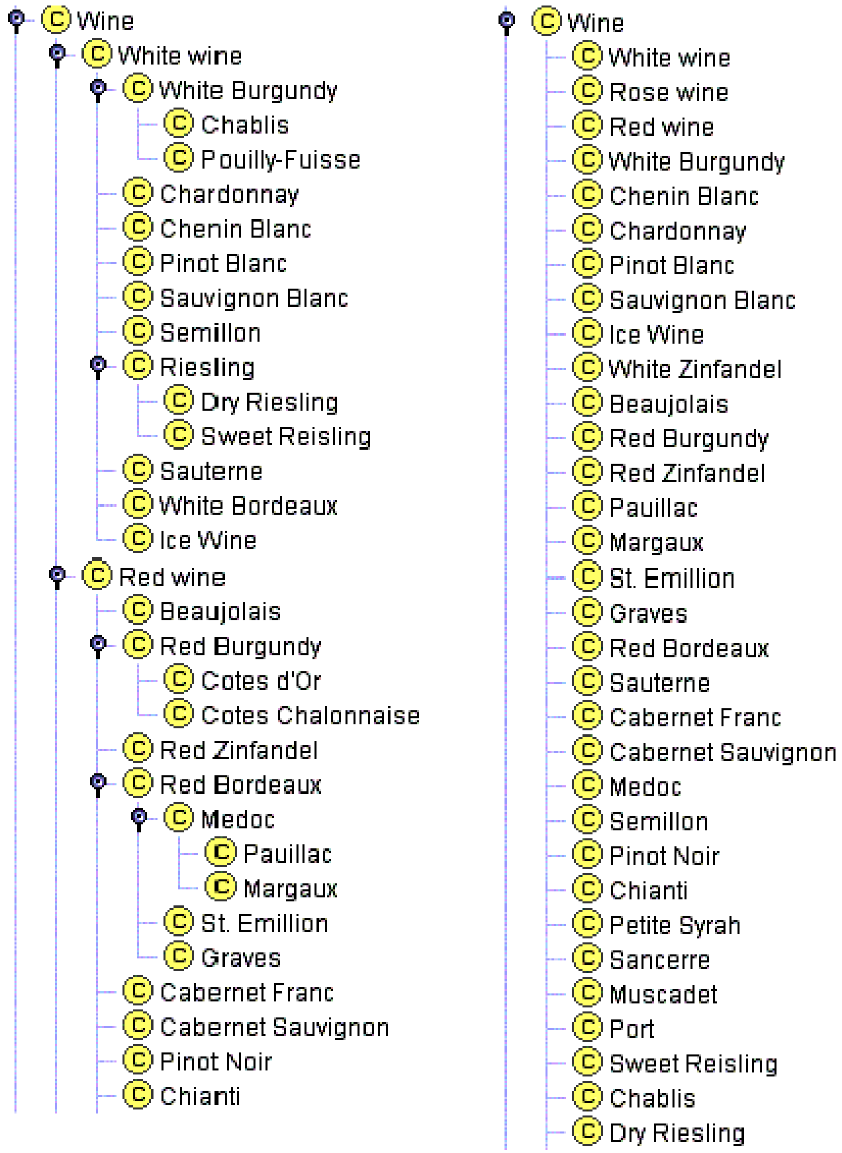

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From https://protege.stanford.edu/publications/ontology_development/ontology101-noy-mcguinness.html

Unpacking Searle’s view

- ~~Conscious~~ mental states are causally reducible to brain states but mental states are ontologically irreducible to brain states
- This has the feel of *maybe* being concrete enough that we can try to build an example of what we think Searle means
- So let's build an agent who exhibits:
  - Mental states that are causally reducible to brain states
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Phenomena of type A are causally reducible to phenomena of type B if and only if:

- the behavior of A’s are entirely casually explained by the behavior of B’s
- A’s have no causal powers in addition to the powers of B’s

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Our objectives

- Unpack a somewhat confusing theory of consciousness by creating a software agent that is consistent with the theory
- Gain a deeper understanding of what the theory means by brain states, by mental states, and the relationship between them through examining the agent

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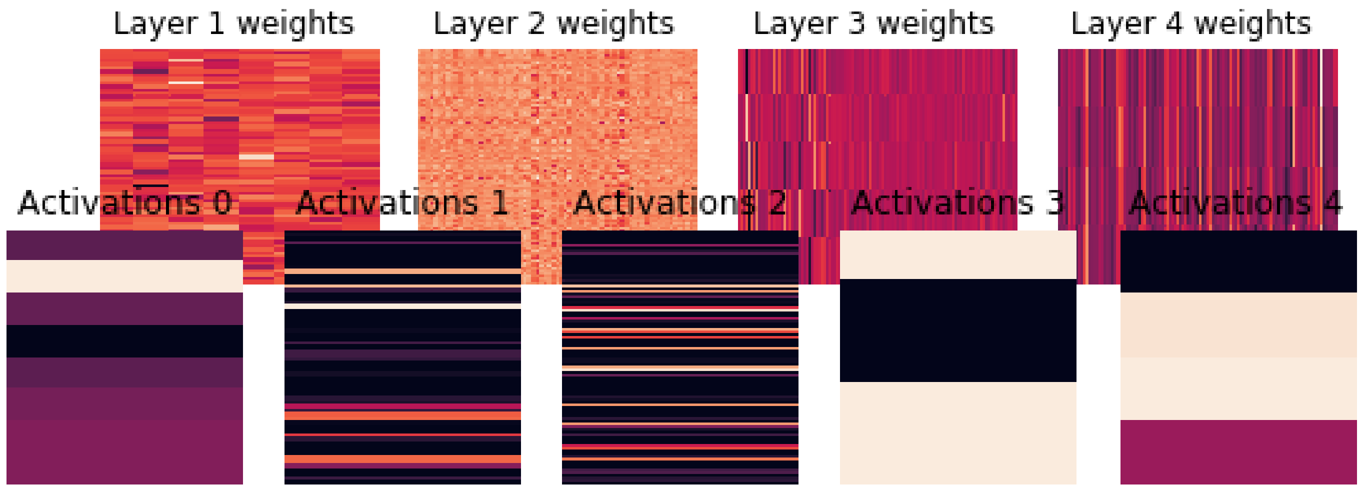
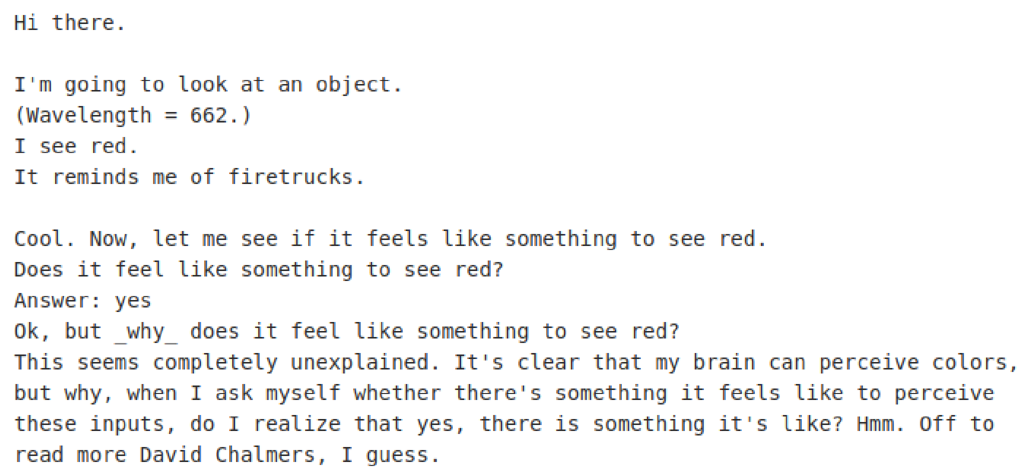
- Standard RL benchmark environment
- A neural network based agent that learns to act in the environment using RL
- A third person ontology (which contains a brain state type)
- A first person ontology of the agent (which contains a mental state type)
- A function that maps brain state types to mental state types
- Simple argument that these objects are consistent with Searle’s claim

Notebook time!

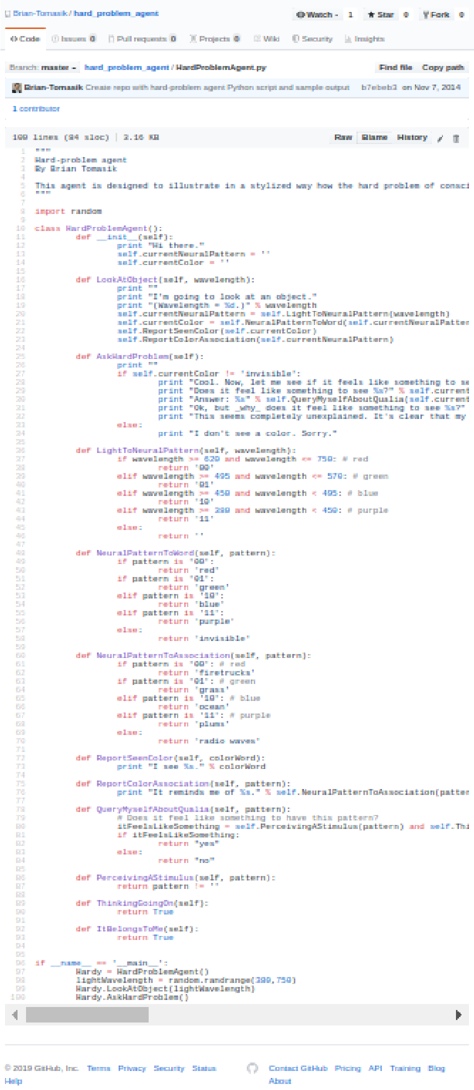


Reifying philosophy with code

- Tomasik: A Simple Program to Illustrate the Hard Problem of Consciousness
- The hard problem is confusing because our brains create a thought that there's something it's like to be us



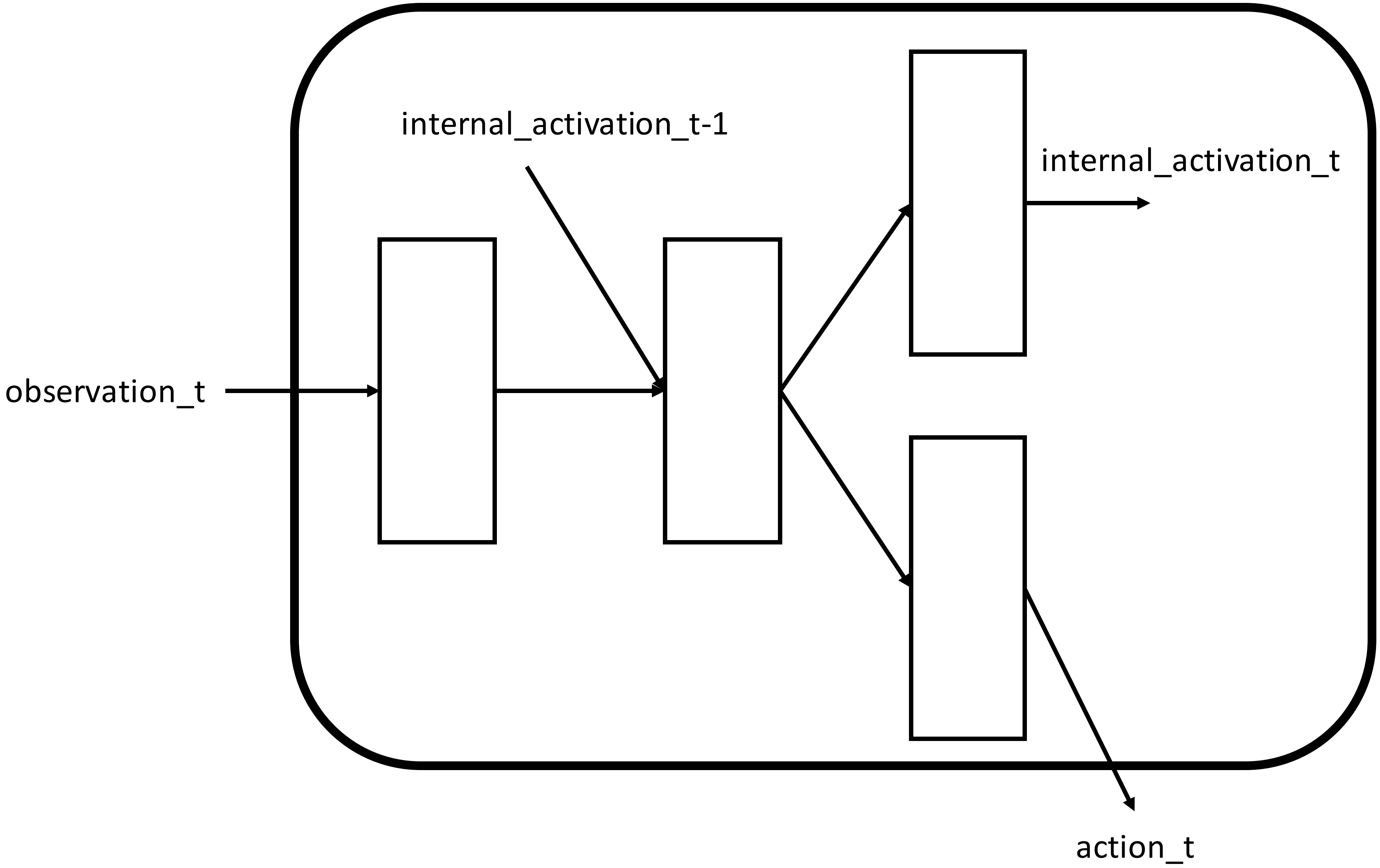
```
Hi there.

I'm going to look at an object.
(Wavelength = 662.)
I see red.
It reminds me of firetrucks.

Cool. Now, let me see if it feels like something to see red.
Does it feel like something to see red?
Answer: yes
Ok, but _why_ does it feel like something to see red?
This seems completely unexplained. It's clear that my brain can perceive colors,
but why, when I ask myself whether there's something it feels like to perceive
these inputs, do I realize that yes, there is something it's like? Hmm. Off to
read more David Chalmers, I guess.
```


Brian-Tomasik / hard_problem_agent
Watch 1
Star 0
Fork 0
Code
Issues 0
Pull requests 0
Projects 0
Wiki
Security
Insights
Branch: master
hard_problem_agent / HardProblemAgent.py
Find file
Copy path
Brian-Tomasik Create repo with hard-problem agent Python script and sample output
b7ebeb3 on Nov 7, 2014
1 contributor
100 lines (94 sloc) | 2.16 KB
Raw
Blame
History

```
"""
Hard-problem agent
By Brian Tomasik

This agent is designed to illustrate in a stylized way how the hard problem of consci
"""

import random

class HardProblemAgent():
        def __init__(self):
                print "Hi there."
                self.currentNeuralPattern = ''
                self.currentColor = ''

        def LookAtObject(self, wavelength):
                print ""
                print "I'm going to look at an object."
                print "(Wavelength = %d.)" % wavelength
                self.currentNeuralPattern = self.LightToNeuralPattern(wavelength)
                self.currentColor = self.NeuralPatternToWord(self.currentNeuralPatter
                self.ReportSeenColor(self.currentColor)
                self.ReportColorAssociation(self.currentNeuralPattern)

        def AskHardProblem(self):
                print ""
                if self.currentColor != 'invisible':
                        print "Cool. Now, let me see if it feels like something to se
                        print "Does it feel like something to see %s?" % self.current
                        print "Answer: %s" % self.QueryMyselfAboutQualia(self.current
                        print "Ok, but _why_ does it feel like something to see %s?"
                        print "This seems completely unexplained. It's clear that my
                else:
                        print "I don't see a color. Sorry."

        def LightToNeuralPattern(self, wavelength):
                if wavelength >= 620 and wavelength <= 750: # red
                        return '00'
                elif wavelength >= 495 and wavelength <= 570: # green
                        return '01'
                elif wavelength >= 450 and wavelength < 495: # blue
                        return '10'
                elif wavelength >= 380 and wavelength < 450: # purple
                        return '11'
                else:
                        return ''

        def NeuralPatternToWord(self, pattern):
                if pattern is '00':
                        return 'red'
                if pattern is '01':
                        return 'green'
                elif pattern is '10':
                        return 'blue'
                elif pattern is '11':
                        return 'purple'
                else:
                        return 'invisible'

        def NeuralPatternToAssociation(self, pattern):
                if pattern is '00': # red
                        return 'firetrucks'
                if pattern is '01': # green
                        return 'grass'
                elif pattern is '10': # blue
                        return 'ocean'
                elif pattern is '11': # purple
                        return 'plums'
                else:
                        return 'radio waves'

        def ReportSeenColor(self, colorWord):
                print "I see %s." % colorWord

        def ReportColorAssociation(self, pattern):
                print "It reminds me of %s." % self.NeuralPatternToAssociation(patter

        def QueryMyselfAboutQualia(self, pattern):
                # Does it feel like something to have this pattern?
                itFeelsLikeSomething = self.PerceivingAStimulus(pattern) and self.Thi
                if itFeelsLikeSomething:
                        return "yes"
                else:
                        return "no"

        def PerceivingAStimulus(self, pattern):
                return pattern != ''

        def ThinkingGoingOn(self):
                return True

        def ItBelongsToMe(self):
                return True


if __name__ == '__main__':
        Hardy = HardProblemAgent()
        lightWavelength = random.randrange(380,750)
        Hardy.LookAtObject(lightWavelength)
        Hardy.AskHardProblem()
```

from https://reducing-suffering.org/simple-program-illustrate-hard-problem-consciousness/

from https://github.com/Brian-Tomasik/hard_problem_agent/blob/master/HardProblemAgent.py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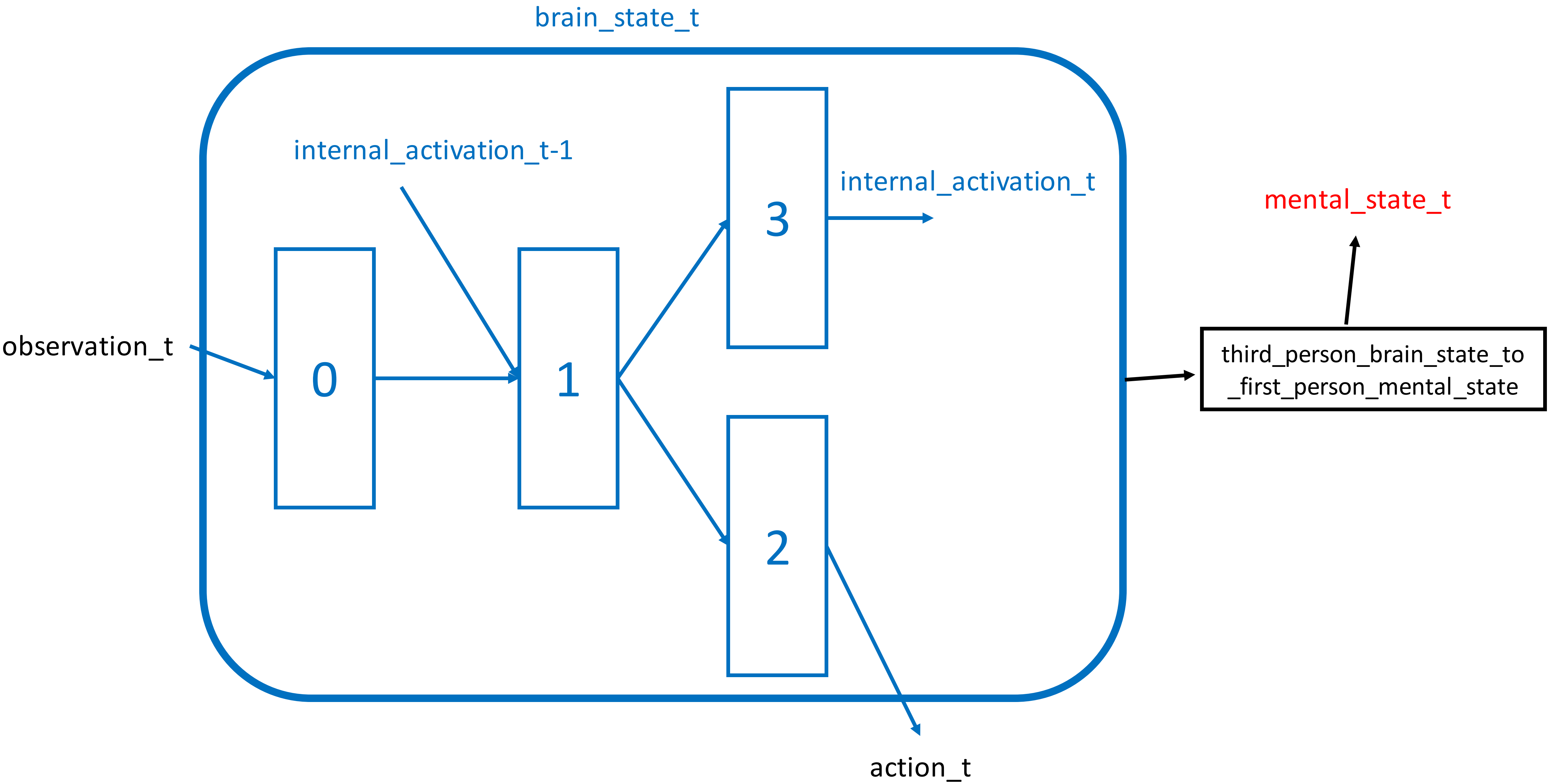
internal_activation_t
observation_t
action_t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3
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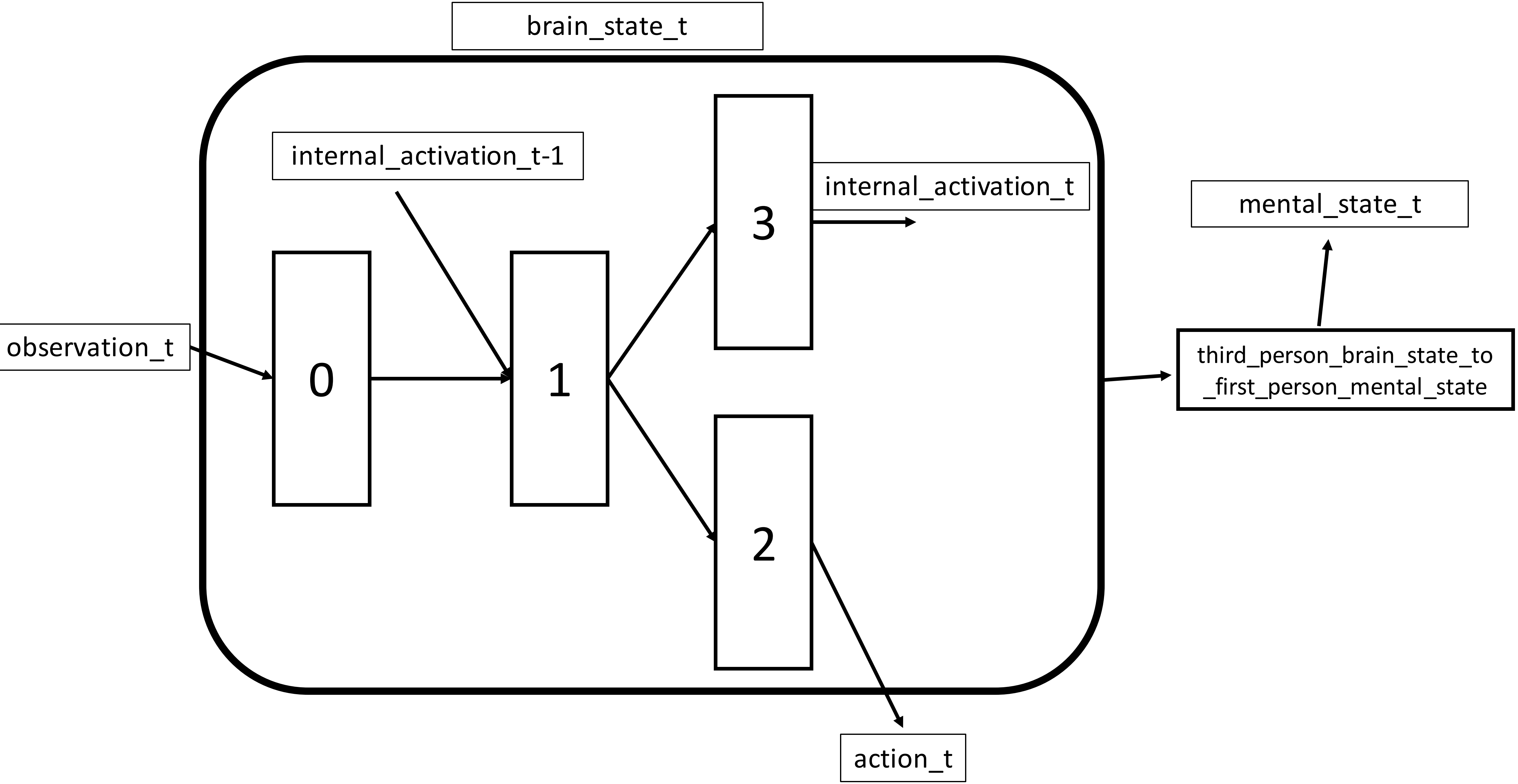
observation_t
0
1
third_person_brain_state_to
_first_person_mental_state
2
action_t



brain_state_t

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internal_activation_t

mental_state_t

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third_person_brain_state_to
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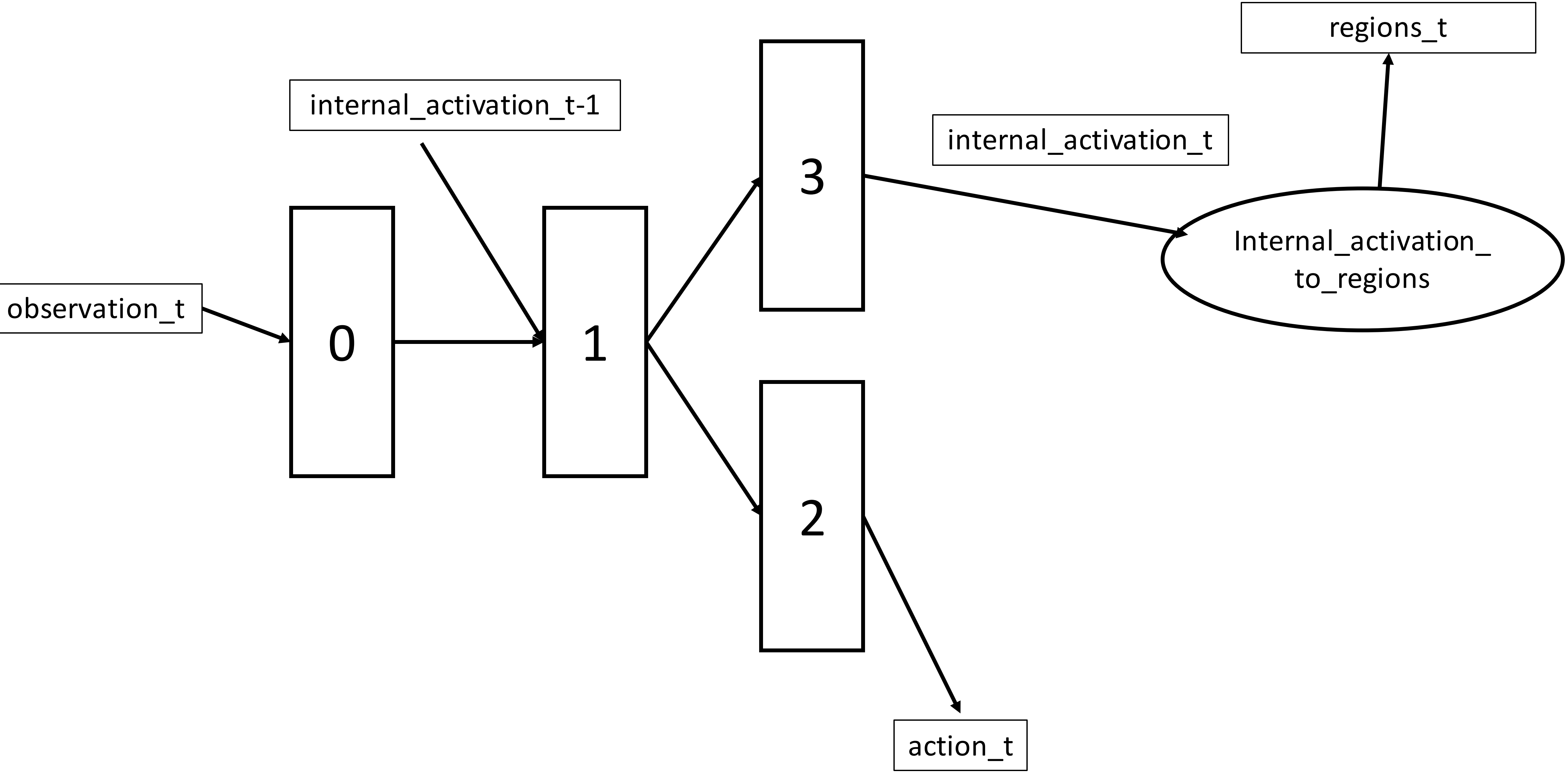
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internal_activation_t
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Internal_activation_
to_regions
observation_t
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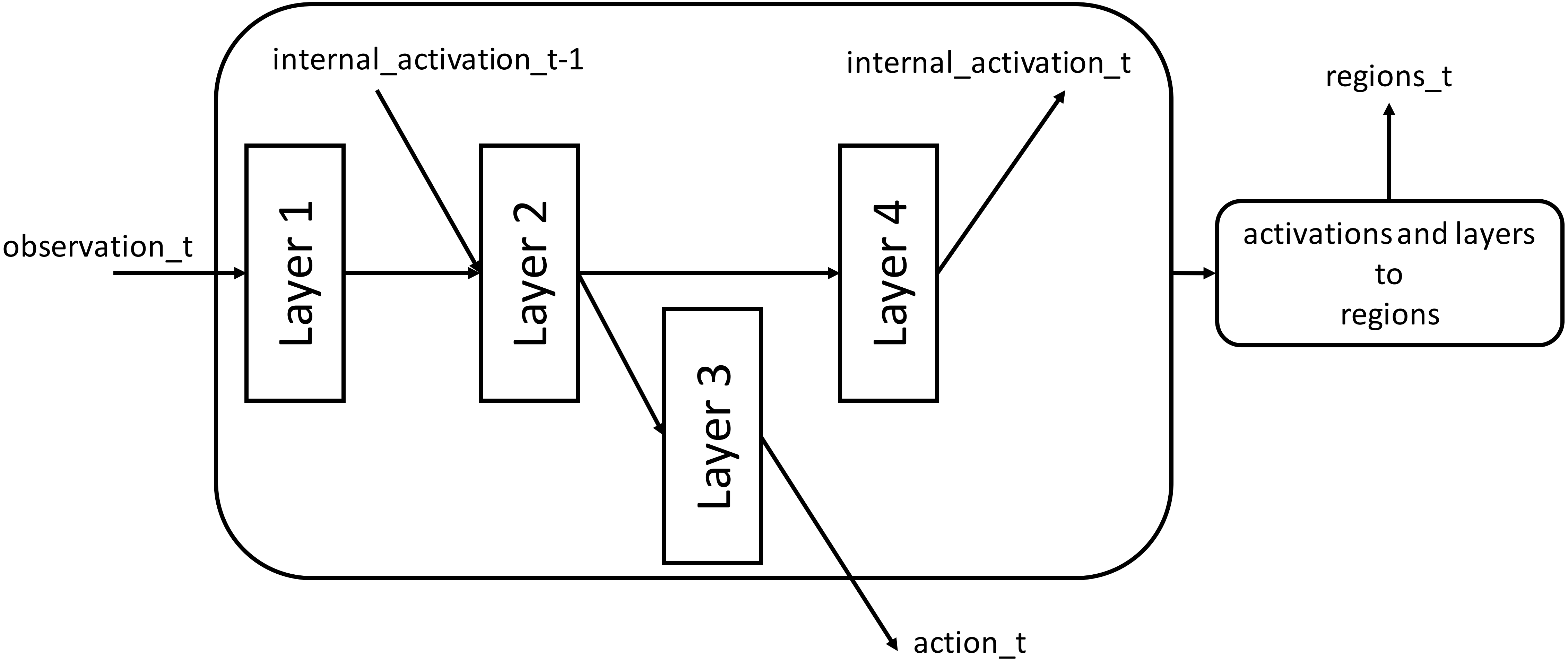
action_t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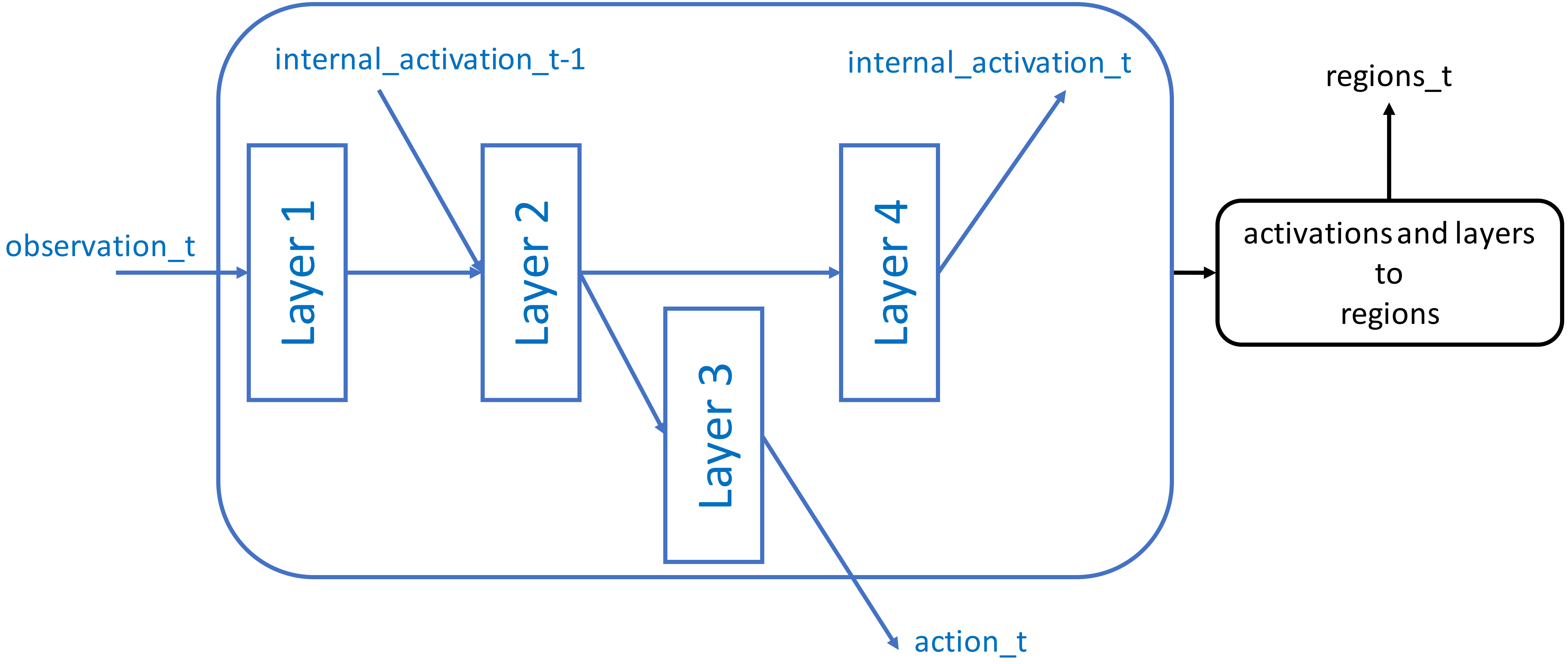
observation_t
Layer 1
Layer 2
Layer 4
Layer 3
activations and layers
to
regions
action_t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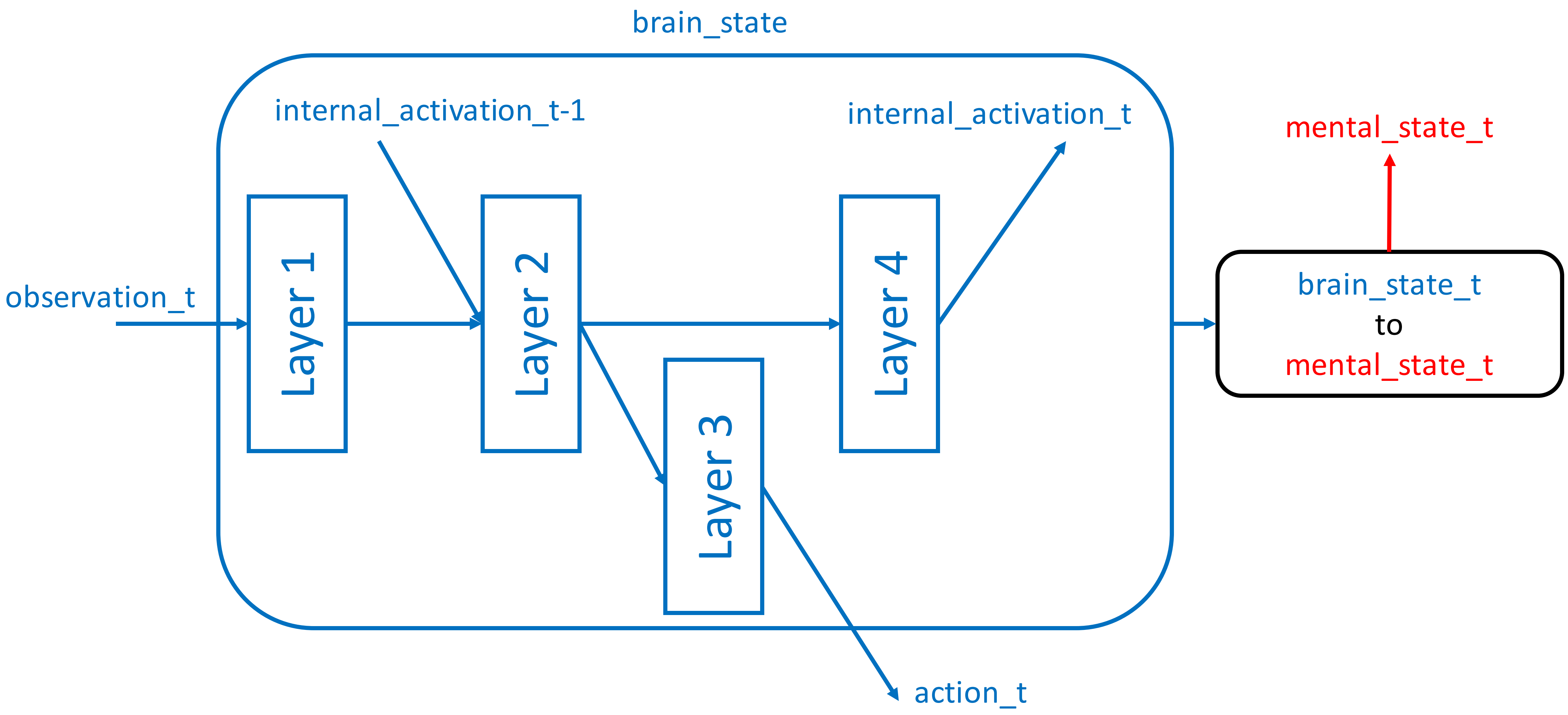
brain_state
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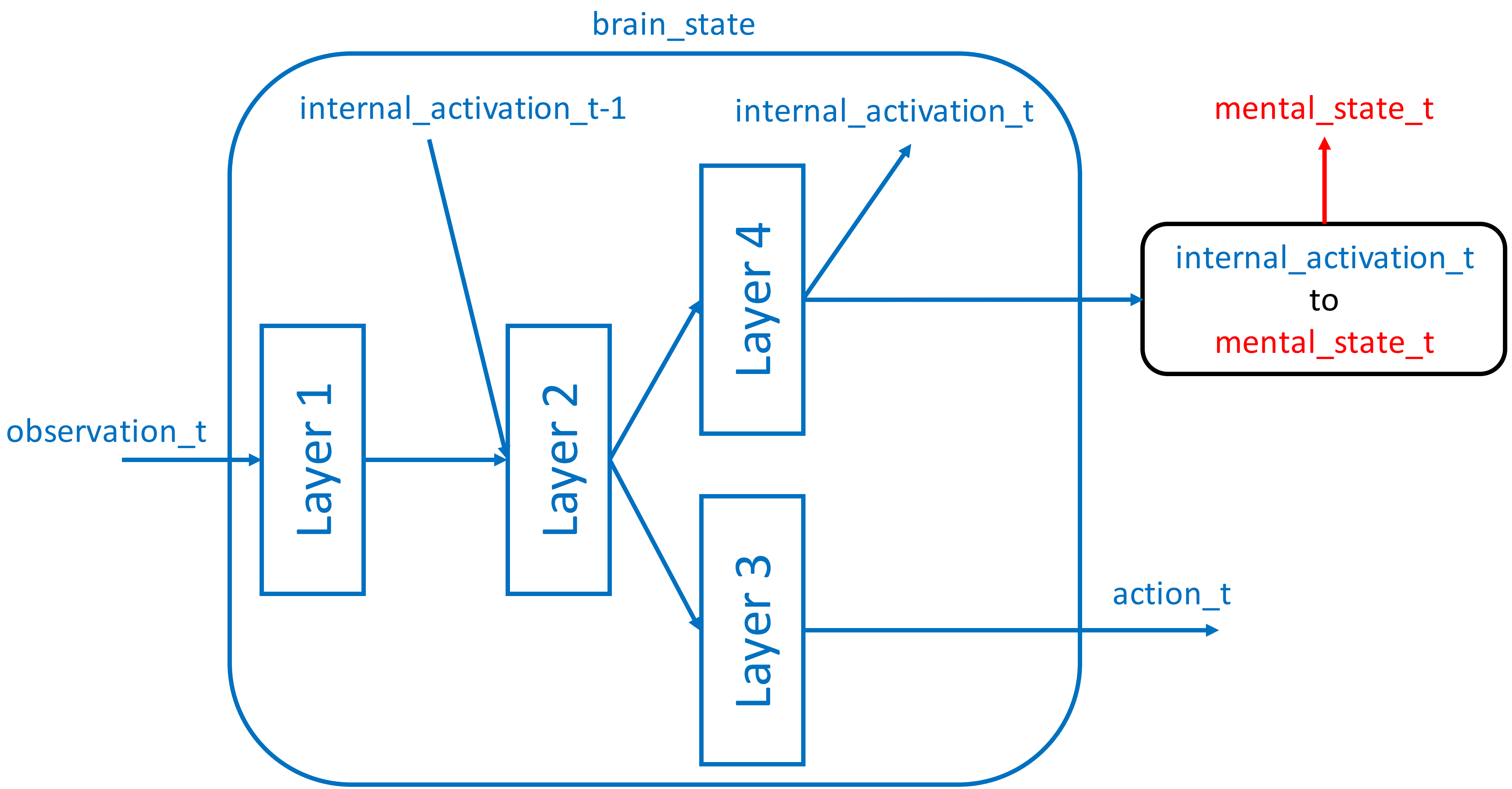
mental_state_t
observation_t
Layer 1
Layer 2
Layer 3
Layer 4
brain_state_t
to
mental_state_t
action_t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Layer 4
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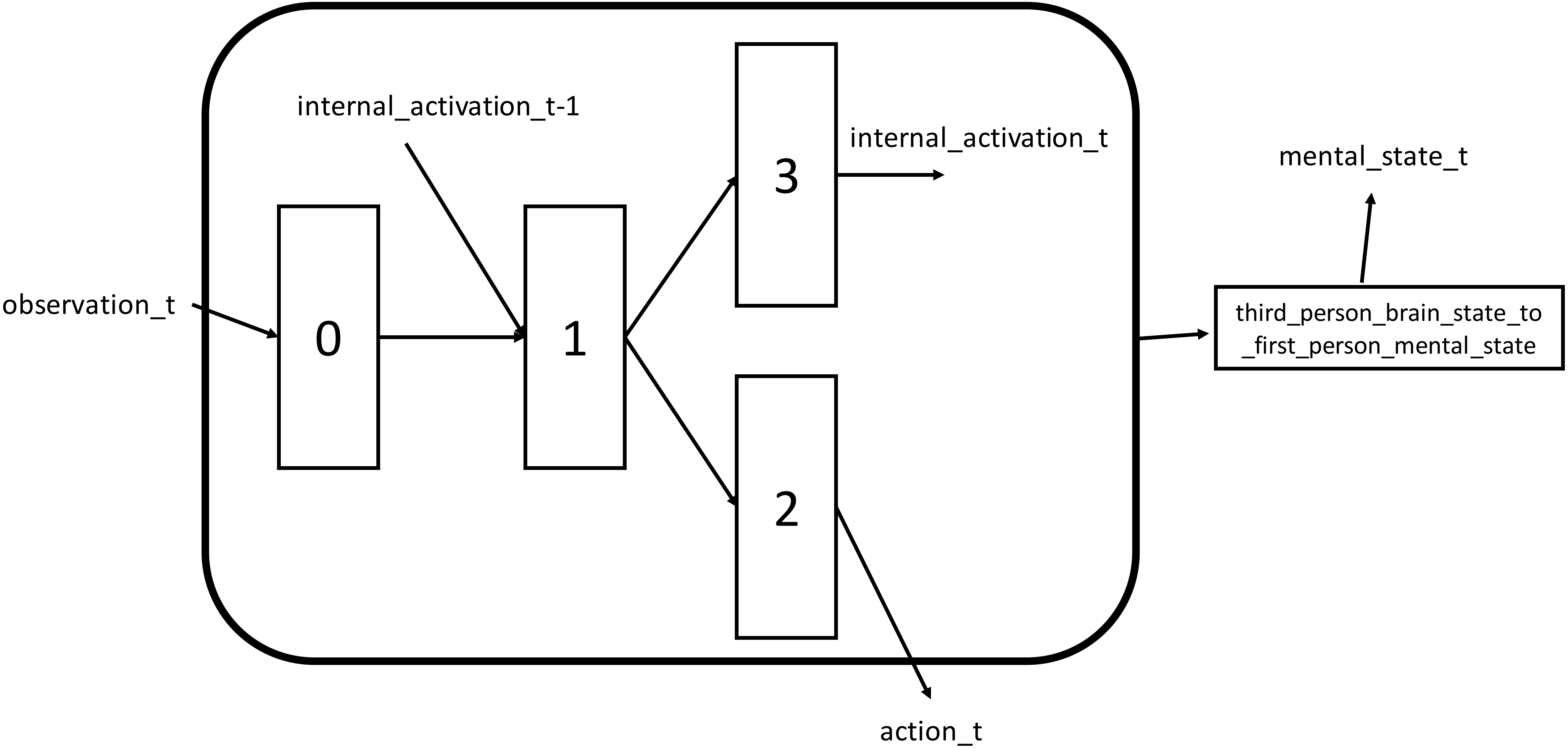
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_first_person_mental_state
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