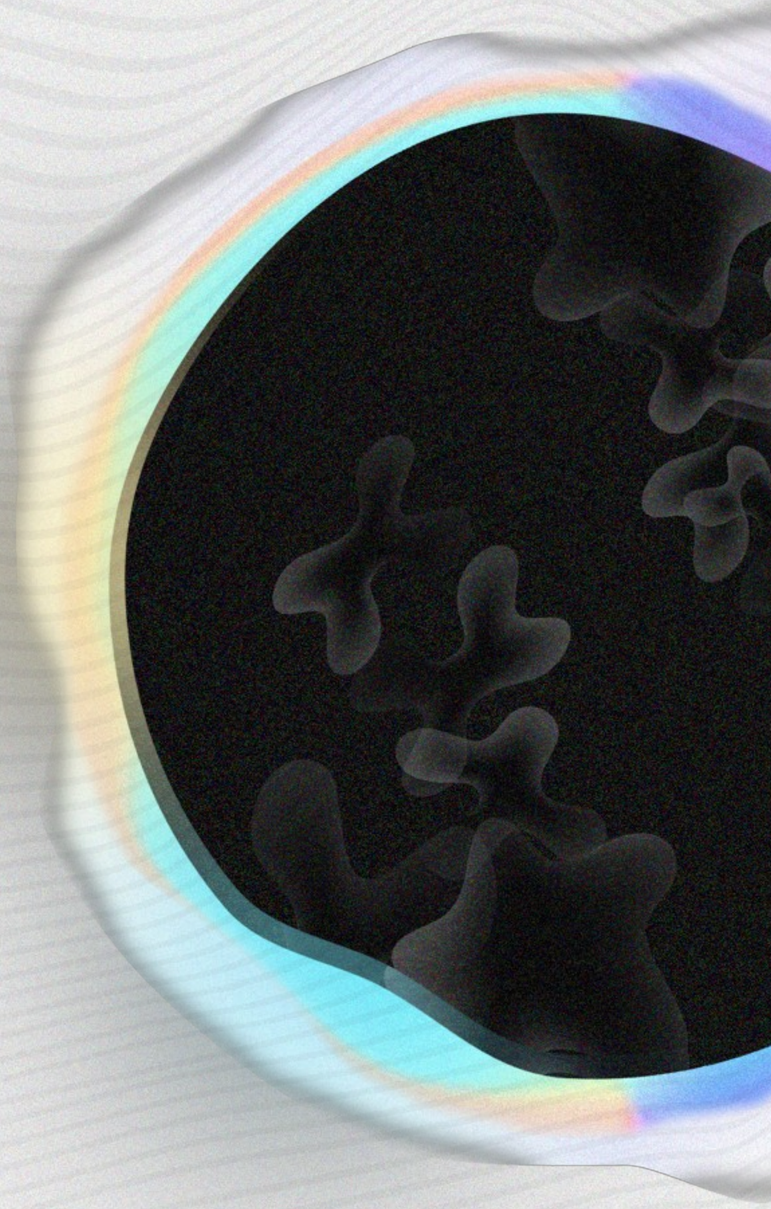
$ https://github.com/singnet/opencog-workshops/intro-singnet

SingularityNET

Introduction to OpenCog



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Content:

Cognitive architectures
Representing knowledge with atomspace
Inference example
Integration with pytorch

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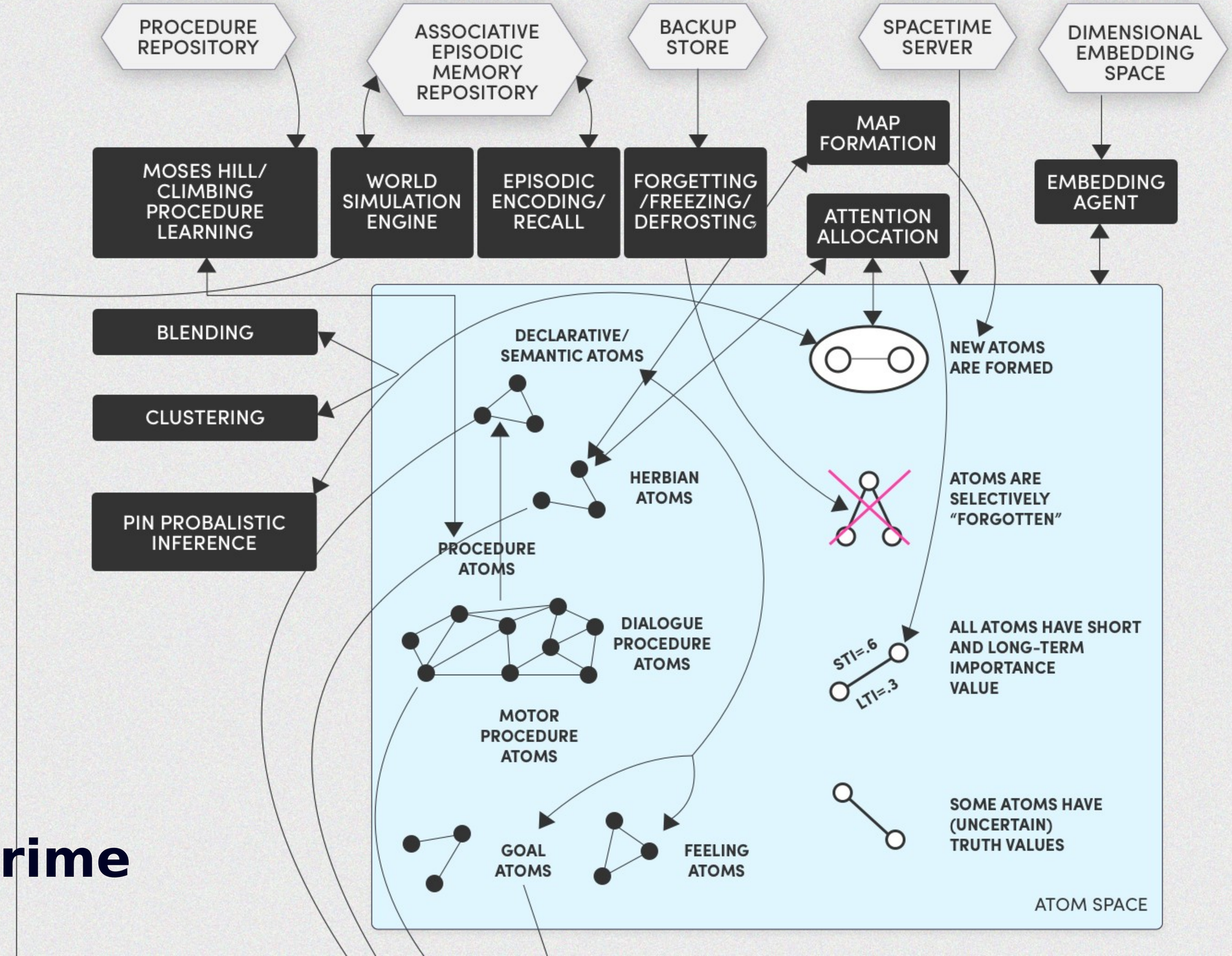
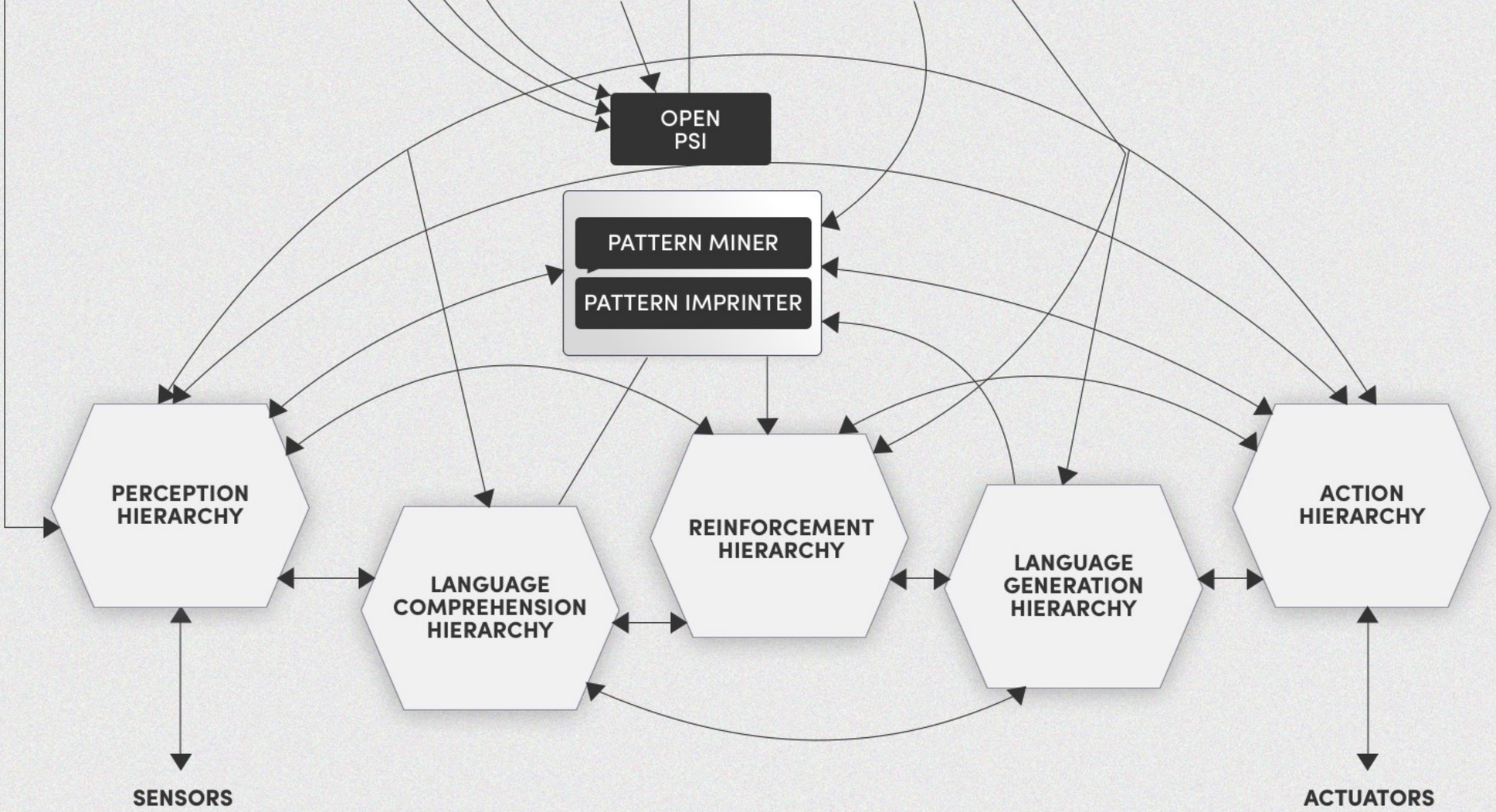
CogPrime


PROCEDURE REPOSITORY
ASSOCIATIVE EPISODIC MEMORY REPOSITORY
BACKUP STORE
SPACETIME SERVER
DIMENSIONAL EMBEDDING SPACE
MOSES HILL/ CLIMBING PROCEDURE LEARNING
WORLD SIMULATION ENGINE
EPISODIC ENCODING/ RECALL
FORGETTING /FREEZING/ DEFROSTING
MAP FORMATION
ATTENTION ALLOCATION
EMBEDDING AGENT
BLENDING
CLUSTERING
PIN PROBALISTIC INFERENCE
DECLARATIVE/ SEMANTIC ATOMS
HERBIAN ATOMS
PROCEDURE ATOMS
DIALOGUE PROCEDURE ATOMS
MOTOR PROCEDURE ATOMS
GOAL ATOMS
FEELING ATOMS
NEW ATOMS ARE FORMED
ATOMS ARE SELECTIVELY "FORGOTTEN"
STI=.6
LTI=.3
ALL ATOMS HAVE SHORT AND LONG-TERM IMPORTANCE VALUE
SOME ATOMS HAVE (UNCERTAIN) TRUTH VALUES
ATOM SPACE


OPEN
PSI
PATTERN MINER
PATTERN IMPRINTER
PERCEPTION
HIERARCHY
LANGUAGE
COMPREHENSION
HIERARCHY
REINFORCEMENT
HIERARCHY
LANGUAGE
GENERATION
HIERARCHY
ACTION
HIERARCHY
SENSORS
ACTUATORS

CogPrime

OpenCog

CogNets

PLN

pattern miner

MOSES

URE

pattern matcher

AtomSpace

Use cases

- Chatbots
- Bioinformatics
- Unsupervised language learning
- Visual Question Answering VQA
- …

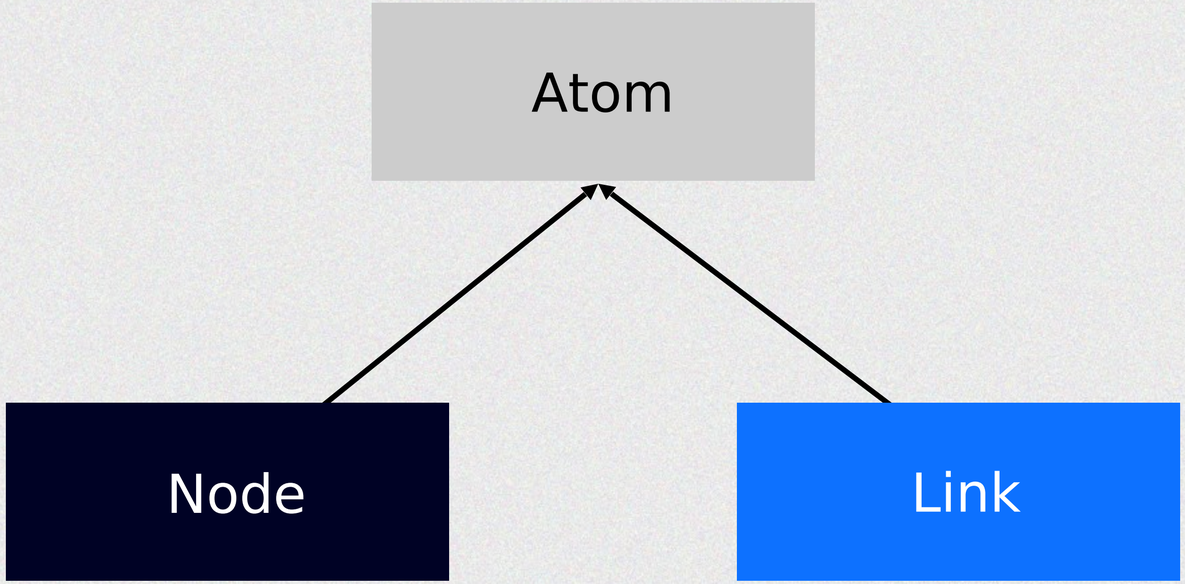
Atomspace - graph database

Hypergraph database designed to be primarily used as a storage of explicit, declarative knowledge

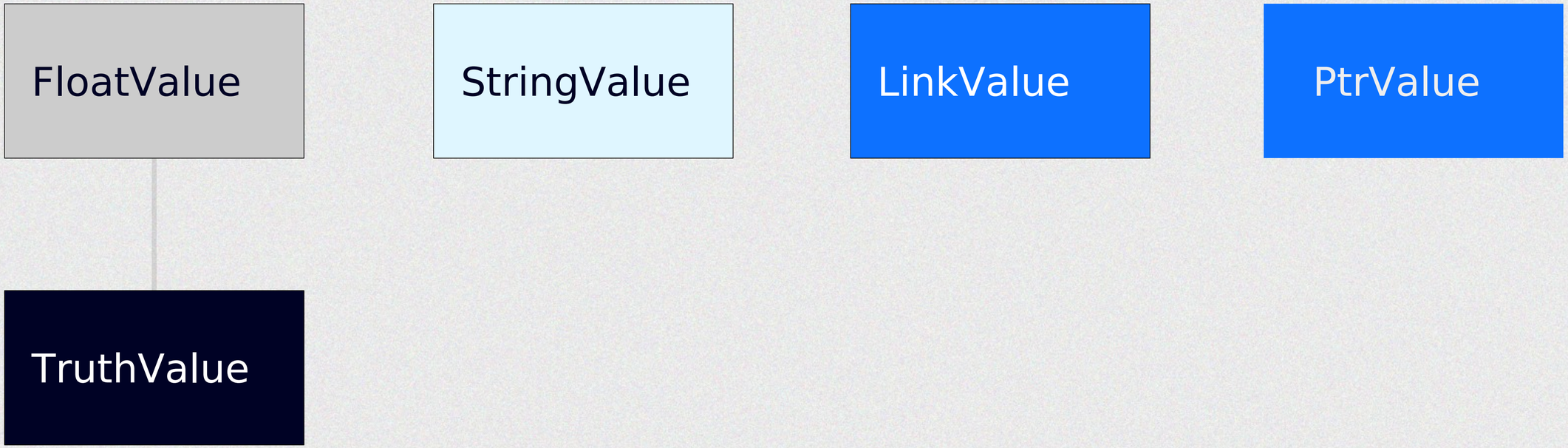
Hypergraph defines programming language - Atomese

Has a number of associated mechanisms:
pattern matching, unified rule engine, moses

Types of data in atomspace: Atoms



Types of data in atomspace: Values



Atomspace - API introduction

Python:

```
>> from opencog.atomspace import AtomSpace, types

>> atomspace = AtomSpace()
```

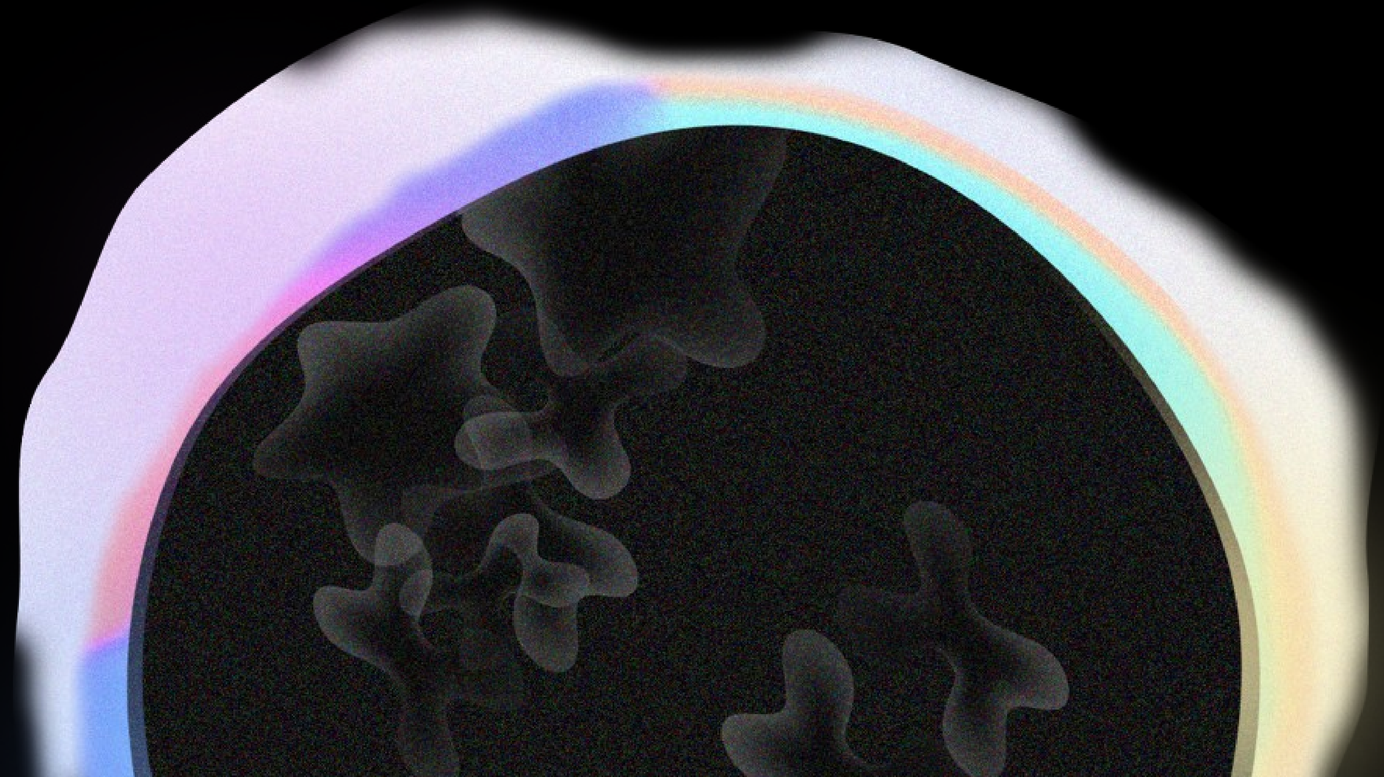
Scheme:

```
scheme> (use-modules (opencog))

scheme> (define atomspace (cog-new-atomspace))
```

AtomSpace examples

```
$ docker run -p8888:8888  -it singnet-demo
$ localhost:8888
```



jupyter

Files | Running | Clusters

Select items to perform actions on them.

0	/	Name	Last Modified
	docker		2 hours ag
	and-link-example.ipynb	Running	2 hours ag
	atomese-examples.ipynb		2 hours ag
	socrates-explained.ipynb		2 hours ag
	socrates.ipynb		2 hours ag
	common.py		2 hours ag

knowledge base

Color and size are attributes.

InheritanceLink is similiar to verb "is" like it is used in natural languages.

```
InheritanceLink(ConceptNode("size"), ConceptNode("attribute"))
InheritanceLink(ConceptNode("color"), ConceptNode("attribute"))
```

Different types of color and size

PredicateNode is used to define relations between different objects.

```
InheritanceLink(PredicateNode("small"), ConceptNode("size"))
InheritanceLink(PredicateNode("big"), ConceptNode("size"))
InheritanceLink(PredicateNode("green"), ConceptNode("color"))
InheritanceLink(PredicateNode("red"), ConceptNode("color"))
InheritanceLink(PredicateNode("black"), ConceptNode("color"))
```

TruthValue

```
> from opencog.atomspace import TruthValue

> tv = TruthValue(0.5, 0.92)

P(Heads) = 0.5, .3

> ConceptNode(“Heads”).tv = tv
```

animals which have some attributes defined using EvaluationLink

EvaluationLink defines predicate for particular objects.

```
def assign_property(concept, relation, tv):
    EvaluationLink(relation,
                   concept).tv = TruthValue(*tv)

assign_property(ConceptNode("frog"), PredicateNode("small"), (0.8, 0.6))
assign_property(ConceptNode("frog"), PredicateNode("green"), (0.7, 0.91))
assign_property(ConceptNode("tiger"), PredicateNode("big"), (0.9, 0.92))
assign_property(ConceptNode("tiger"), PredicateNode("red"), (0.6, 0.83))
assign_property(ConceptNode("sparrow"), PredicateNode("red"), (0.1, 0.64))
assign_property(ConceptNode("sparrow"), PredicateNode("small"), (0.8, 0.77))
assign_property(ConceptNode("zebra"), PredicateNode("black"), (0.5, 0.9))
assign_property(ConceptNode("zebra"), PredicateNode("small"), (0.38, 0.89))
```

Define that all animals are actually animals

```
InheritanceLink(ConceptNode("frog"), ConceptNode("animal"))
InheritanceLink(ConceptNode("frog"), ConceptNode("animal"))
InheritanceLink(ConceptNode("tiger"), ConceptNode("animal"))
InheritanceLink(ConceptNode("tiger"), ConceptNode("animal"))
InheritanceLink(ConceptNode("sparrow"), ConceptNode("animal"))
InheritanceLink(ConceptNode("sparrow"), ConceptNode("animal"))
InheritanceLink(ConceptNode("zebra"), ConceptNode("animal"))
InheritanceLink(ConceptNode("zebra"), ConceptNode("animal"))
```

BindLink and pattern matcher

BindLink

<variables> - optional
<pattern to match>
<rewrite term>

Pattern example:

```
ListLink(ConceptNode("red"),
        VariableNode("$X"),
        ConceptNode("blue"))
```

Basic query example

select all red animals:

Find all the EvaluationLink with predicate "red"

```
bind_link = BindLink(
                    EvaluationLink(PredicateNode("red"),
                                   VariableNode("X")),
                    VariableNode("X"))
```

```
print(execute_atom(atomspace, bind_link))
```

```
   (SetLink
     (ConceptNode "tiger")
     (ConceptNode "sparrow")
   )
```

Query example

let's select all animals and attributes, filtering by some threshold

first define function and EvaluationLink

```
threshold = 0.6

def apply_threshold(atom):
    if atom.tv.mean < threshold:
        return TruthValue(0, 1)
    return TruthValue(1, 1)
```

Constrain Variable("X") is animal

```
is_animal = InheritanceLink(VariableNode("X"),
                            ConceptNode("animal"))
```

EvaluationLink will accept link X <- "animal" and return flag if it "matches"

```
predicate = EvaluationLink(VariableNode("$B"),
                           VariableNode("X"))

eval_threshold = EvaluationLink(
                     GroundedPredicateNode("py: apply_threshold"),
                     ListLink(predicate))
```

first define pattern that will be grounded during the search

```
and_link = AndLink(is_animal,
                   predicate,
                   eval_threshold
                  )
```

---

now build the BindLink

BindLink is constructed using pattern to ground and pattern to return.
pattern to return if it contains variables,
should be part of pattern to ground

```
bindlink_filter = BindLink(and_link,
                           predicate)
```

```
print(execute_atom(atomspace, bindlink_filter))
```

```
(SetLink
  (EvaluationLink (stv 0.900000 0.920000)
    (PredicateNode "big")
    (ConceptNode "tiger")
  )
  (EvaluationLink (stv 0.800000 0.770000)
    (PredicateNode "small")
    (ConceptNode "sparrow")
  )
  (EvaluationLink (stv 0.600000 0.830000)
    (PredicateNode "red")
    (ConceptNode "tiger")
  )
  (EvaluationLink (stv 0.700000 0.910000)
    (PredicateNode "green")
    (ConceptNode "frog")
  )
```

Unified Rule Engine

Inference engine based on graph rewriting rules.

Allows to perform declarative inference.

Rules and data defined in the same language - atomese

Can do backward and forward chaining

Unified Rule Engine

Inference in first-order logic

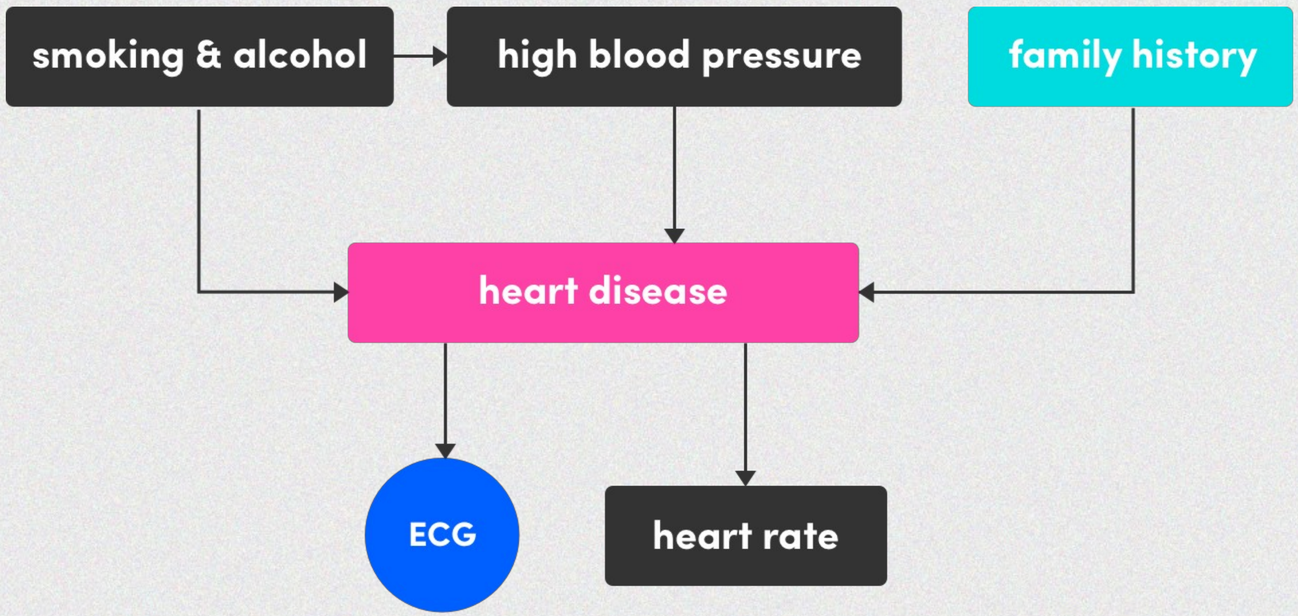
Automatic differentiation

Graphical models

Probabilistic logic inference

Fuzzy logic inference

...



docker

and-link-example.ipynb

atomese-examples.ipynb

socrates-explained.ipynb

socrates.ipynb Running

common.py

LICENSE

notebook.sh

opencog.log

README.md

Defining problem

```
> InheritanceLink(ConceptNode("Socrates"),
                  ConceptNode("man")).tv =
                TruthValue(0.97, 0.92)
> InheritanceLink(ConceptNode("man"),
                  ConceptNode("mortal")).tv =
                TruthValue(0.98, 0.94)
InheritanceLink(ConceptNode("Socrates"),
                  ConceptNode("mortal")).tv = ???
```

[5]:
```
pattern = InheritanceLink(ConceptNode("Socrates"), ConceptNode("mortal"))
```

Specify rule base.
All rule inheriting from ConceptNode("PLN") will be considired by the rule engine

[6]:
```
rule_base = ConceptNode("PLN")
```

Construct BackwardChainer object
It's arguments are atomspace, rule_base, and pattern to infer

[7]:
```
chainer = BackwardChainer(atomspace, rule_base, pattern)
chainer.do_chain()
print(chainer.get_results())
```

```
(SetLink
```

Running backward chainer

```
> request =
InheritanceLink(ConceptNode("Socrates"),
                ConceptNode("mortal"))
> tr = AtomSpace() # trace atomspace
> rule_base = ConceptNode("PLN") # rules to use
> chainer = BackwardChainer(atomspace, rule_base,
      request,
      trace_as=tr)
> chainer.do_chain()
> print(chainer.get_results())
```

Result

```
> (SetLink
    (InheritanceLink (stv 0.9508 0.828)
    (ConceptNode(“Socrates”),
    (ConceptNode("mortal"))
```

Deduction rule example

premise condition = AndLink(BA, CB)

A -> B BA = InheritanceLink(var_b, var_a)

B -> C CB = InheritanceLink(var_c, var_b)

Ergo: A -> C

```
rewrite = ExecutionOutputLink(
        GroundedSchemaNode("scm: deduction-formula"),
        ListLink(CA, CB, BA))

deduction_link = BindLink(condition, rewrite)
```

Rule structure:

BindLink

<variables>

AndLink

<premise-1>

...

<premise-n>

<conclusion-pattern>

1 / cog_module

..

mnist.ipynb

example.py

mnist.py

module.py

opencog.log

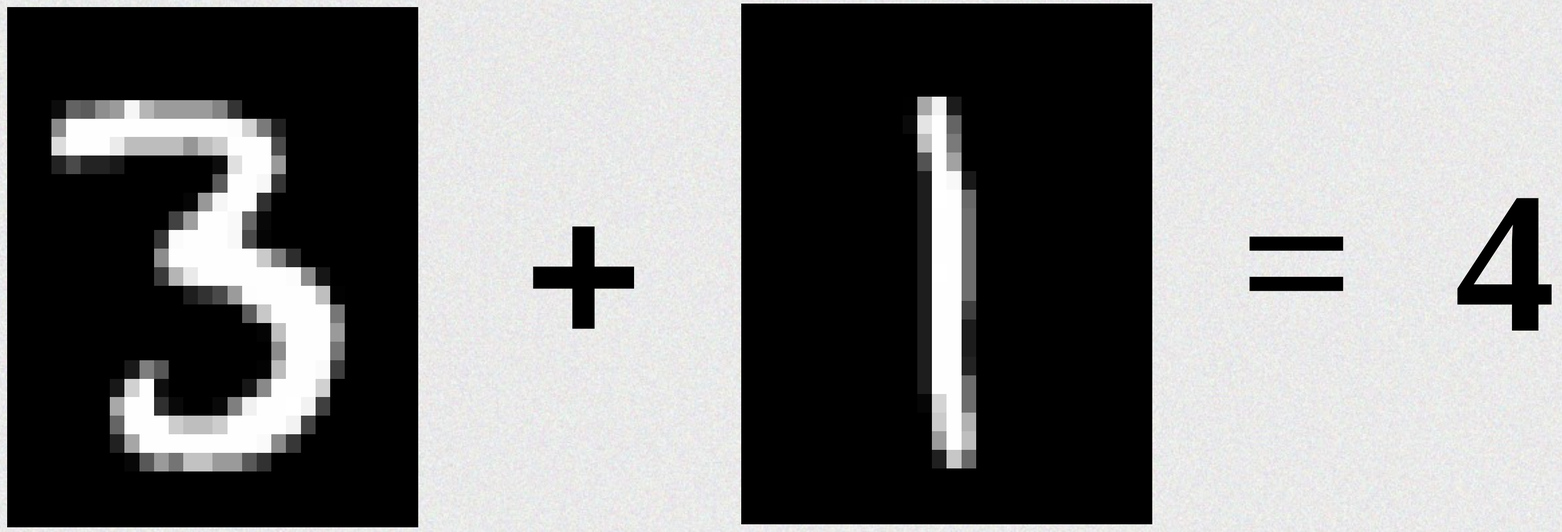
pln.py

test.py

mnist example

inputs

label



mnist example

$$p(label=4)=\sum \begin{matrix} p(3)\cdot p(1) \\ p(1)\cdot p(3) \\ p(2)\cdot p(2) \\ p(4)\cdot p(0) \\ p(0)\cdot p(4) \end{matrix}$$

CogModule

CogModule is python class that attaches itself to an Atom.

It has number of helper methods to generate queries in Atomese

```
class MnistNet(CogModule):
    def __init__(self, atom):
        super().__init__(atom)
        self.conv1 = nn.Conv2d(1, 20, 5, 1)
        self.conv2 = nn.Conv2d(20, 50, 5, 1)
        self.fc1 = nn.Linear(4*4*50, 500)
        self.fc2 = nn.Linear(500, 10)

    def forward(self, x):
        x = F.relu(self.conv1(x))
        x = F.max_pool2d(x, 2, 2)
        x = F.relu(self.conv2(x))
```

mnist example

$$\sum \begin{array}{l} ProbOfDigit(3) \cdot ProbOfDigit(1) \\ ProbOfDigit(1) \cdot ProbOfDigit(3) \\ ProbOfDigit(2) \cdot ProbOfDigit(2) \\ ProbOfDigit(4) \cdot ProbOfDigit(0) \\ ProbOfDigit(0) \cdot ProbOfDigit(4) \end{array}$$

```
class Multiply(CogModule):
    def forward(self, x, y):
        return x * y

class ProbOfDigit(CogModule):
    def forward(self, probs, i, p_in_range):
        return probs[0][i] * p_in_range

class ProbSum(CogModule):
    def forward(self, *args):
        result = sum(args)
        if result > 1:
            raise RuntimeError("probability exceeds 1")
        return result
```

CogModel

CogModel is class for holding all learnable parameters. Also it provides methods to execute queries. Such wrappers are necessary to deal with caching.

```
class MnistModel(CogModel):
    def __init__(self, atomspace):
        super().__init__()
        self.atomspace = atomspace
        self.mnist = MnistNet(ConceptNode("mnist"))
        self.sum_prob = SumProb(ConceptNode("SumProb"))
        self.digit_prob = ProbOfDigit(ConceptNode("ProbOfDigit"))
        self.torch_sum = TorchSum(ConceptNode("TorchSum"))
        self.inh_weights = torch.nn.Parameter(torch.Tensor([0.3] * 10))
        #  create NumberNodes
        #  attach tensor representing p(number in range)
        for i in range(10):
            NumberNode(str(i)).set value(PredicateNode("cogNet"), PtrVal
```

```
def process(self, data, label):
    """
    Accepts batch with features and labels,
    returns probability of labels
    """
    with tmp_atomspace() as atomspace:
        #  compute possible pairs of NumberNodes
        pairs = self.get_all_pairs(label, atomspace)

        # setup input images
        inp1 = InputModule(ConceptNode("img1"), data[0].reshape([1,
        inp2 = InputModule(ConceptNode("img2"), data[1].reshape([1,
        return self.p_correct_answer(pairs, inp1, inp2)


def p_correct_answer(self, pairs, inp1, inp2):
    """
    compute probability of earch pair
```

```
def get_all_pairs(self, label, atomspace):
    """
    Calculate all suitable pairs of digits for given
    """
    label = str(int(label.sum()))
    var_x = atomspace.add_node(types.VariableNode, "X
    var_y = atomspace.add_node(types.VariableNode, "Y
    vardecl = VariableList(TypedVariableLink(var_x, T
    eq = EqualLink(PlusLink(var_x, var_y), NumberNode
    inh1 = InheritanceLink(var_x, ConceptNode("range"
    inh2 = InheritanceLink(var_y, ConceptNode("range"
    bindlink = BindLink(vardecl, AndLink(inh1, inh2,
    return execute_atom(atomspace, bindlink)
```

```
def p_correct_answer(self, pairs, inp1, inp2):
    """
    compute probability of earch pair
    compute total probability - sum of pairs
    """
    lst = []
    p_digit = lambda mnist, digit, inh: self.digit_prob.execute(mnist
    for pair in pairs.out:
        p_digit1 = p_digit(self.mnist.execute(inp1.execute()),
                           pair.out[0],
                           InheritanceLink(pair.out[0], ConceptNode("range")))
        p_digit2 = p_digit(self.mnist.execute(inp2.execute()),
                           pair.out[1],
                           InheritanceLink(pair.out[1], ConceptNode("range")))
        sum_expr = self.sum_prob.execute(p_digit1, p_digit2)
        lst.append(sum_expr)
    sum_query = self.torch_sum.execute(*lst)
    result = self.execute_atom(sum_query)
    return result
```

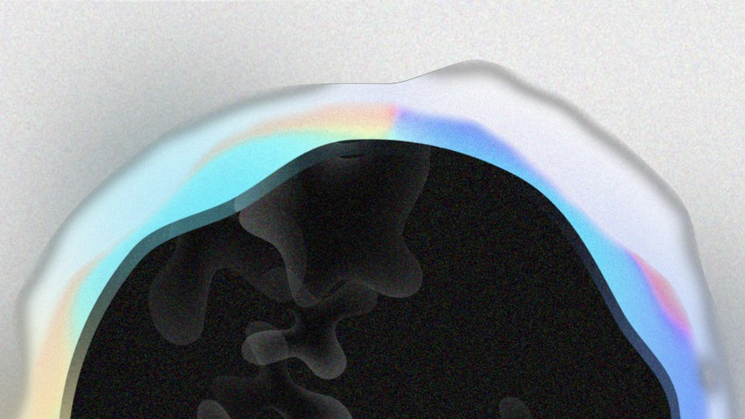
Integrating opencog with neural networks

CogNets

Passing arbitrary python objects between ExecutionOutputLinks

Allows to express computation graph as pytorch expression

Allows to integrate and update ontologies



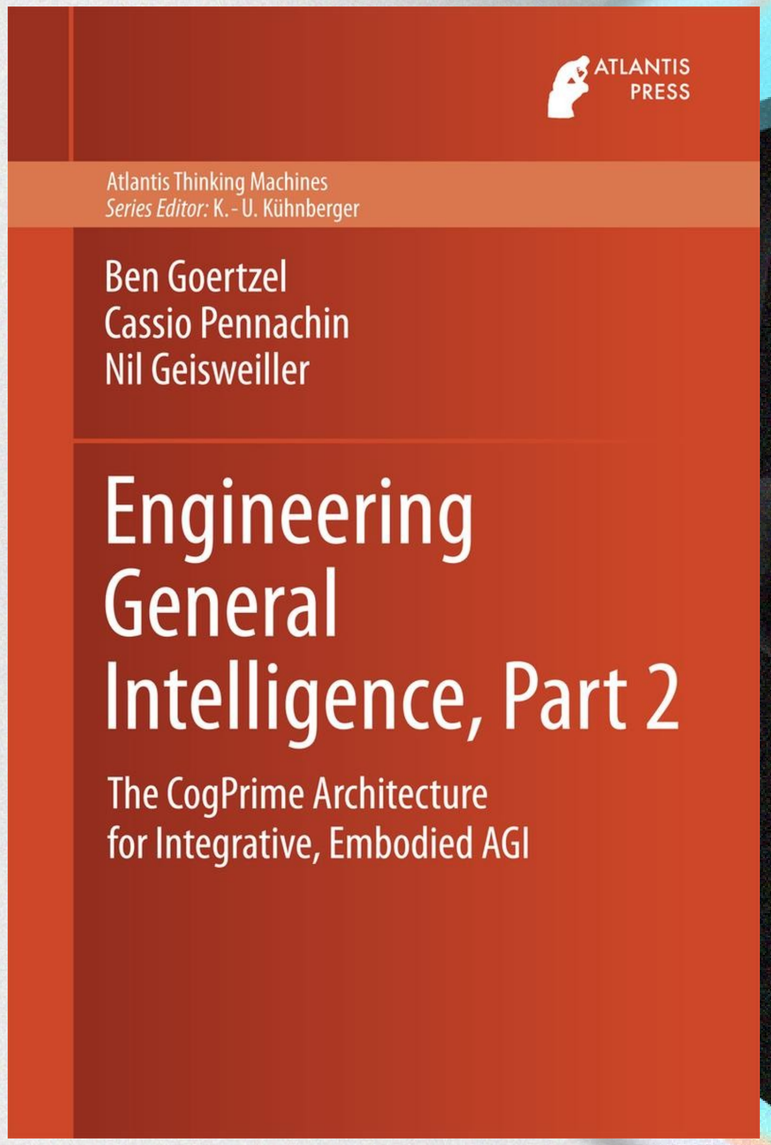
Resources

wiki.opencog.org/

github.com/opencog/

github.com/singnet/semantic-vision

blog.singularitynet.io



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