Dreamcoder: Bootstrapping Inductive Program Synthesis With Wake-Sleep Library Learning

Kevin Ellis
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2021

Synthesis of Models and Systems

The premise of program induction

1. Represent knowledge as programs: as symbolic code

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2. Learning=adding to that body of knowledge=
   making new programs=program synthesis

Why program induction?

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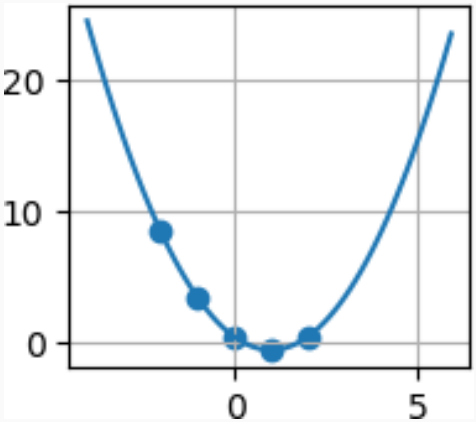
strong generalization

+data efficiency

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f(x)=(x-1)**2 - 0.5
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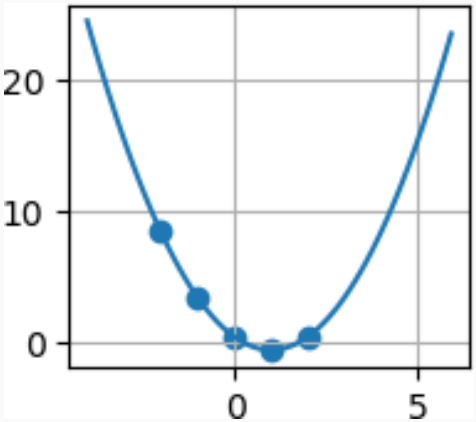


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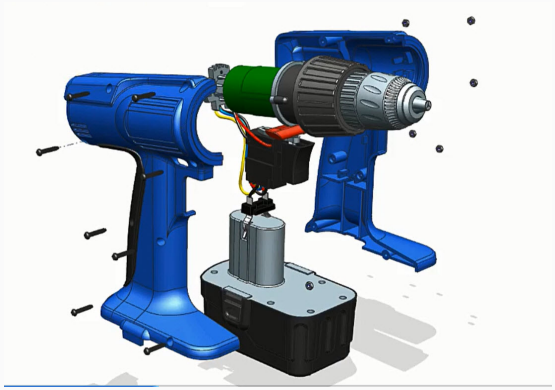
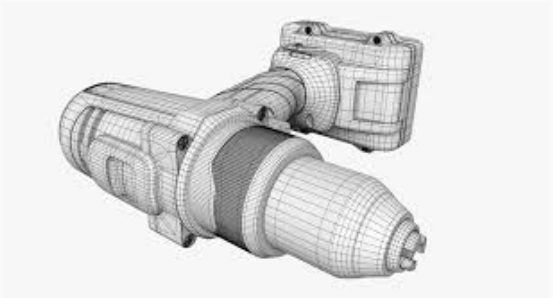


vs



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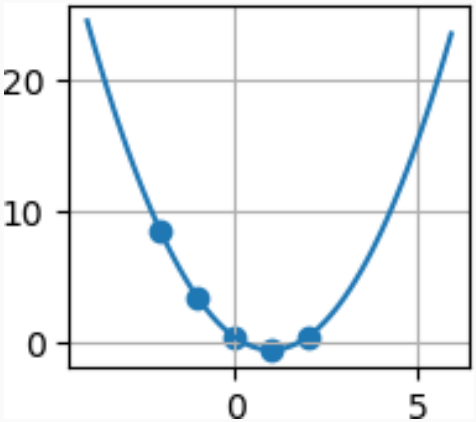


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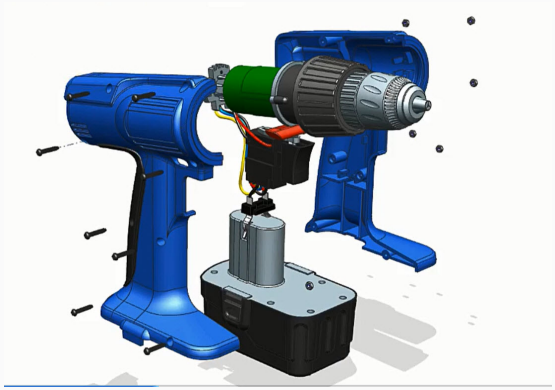

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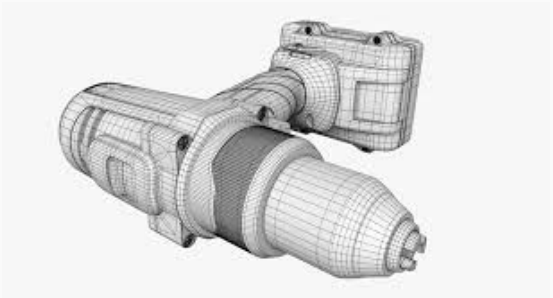
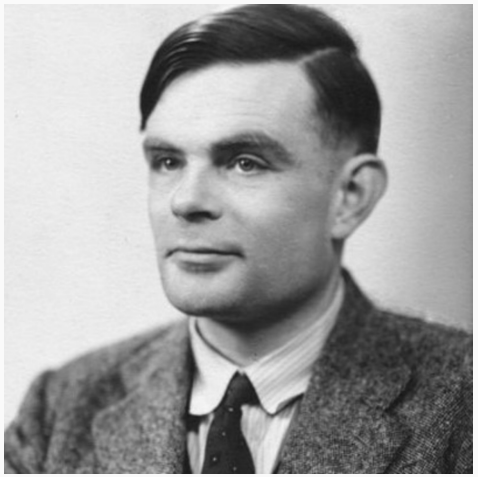


universal expressivity



FlashFill (Gulwani 2012)

EXAMPLE 3 (Directory Name Extraction). *Consider the following example taken from an excel online help forum.*

Input v_1	*Output*
Company\Code\index.html	*Company\Code*
Company\Docs\Spec\specs.doc	*Company\Docs\Spec*

String Program:

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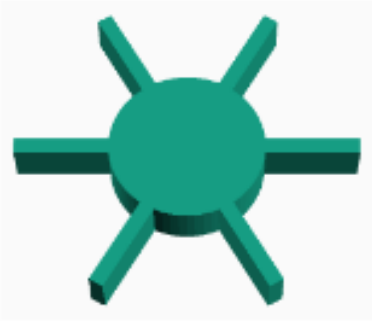
Szalinski (Nandi 2020)



(a) CAD model of ship's wheel

```
(Union
 (Cylinder [1, 5, 5])
 (Fold Union
  (Tabulate (i 6)
   (Rotate [0, 0, 60i]
    (Translate [1, −0.5, 0]
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```

(b) Caddy program

FlashFill (Gulwani 2012)

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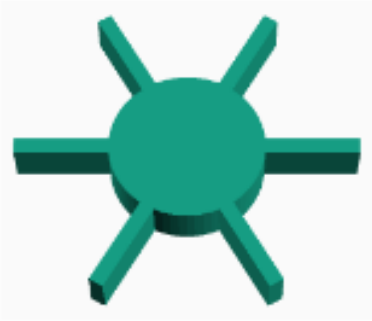
$$
\begin{array}{rcl}
\text{String expr } P & := & \texttt{Switch}((\mathrm{b}_1, \mathrm{e}_1), \cdot\cdot, (\mathrm{b}_n, \mathrm{e}_n)) \\
\text{Bool b} & := & \mathrm{d}_1 \vee \cdot\cdot \vee \mathrm{d}_n \\
\text{Conjunct d} & := & \pi_1 \wedge \cdot\cdot \wedge \pi_n \\
\text{Predicate } \pi & := & \texttt{Match}(v_i, \mathrm{r}, k) \mid \neg\, \texttt{Match}(v_i, \mathrm{r}, k) \\
\text{Trace expr e} & := & \texttt{Concatenate}(\mathrm{f}_1, \cdot\cdot, \mathrm{f}_n) \\
\text{Atomic expr f} & := & \texttt{SubStr}(v_i, \mathrm{p}_1, \mathrm{p}_2) \\
 & \mid & \texttt{ConstStr}(s) \\
 & \mid & \texttt{Loop}(\lambda w : \mathrm{e}) \\
\text{Position p} & := & \texttt{CPos}(k) \mid \texttt{Pos}(\mathrm{r}_1, \mathrm{r}_2, \mathrm{c}) \\
\text{Integer expr c} & := & k \mid k_1 w + k_2 \\
\text{Regular Expression r} & := & \texttt{TokenSeq}(\mathrm{T}_1, \cdot\cdot, \mathrm{T}_m) \\
\text{Token T} & := & C+ \mid [\neg C]+ \\
 & \mid & \text{SpecialToken}
\end{array}
$$

Szalinski (Nandi 2020)



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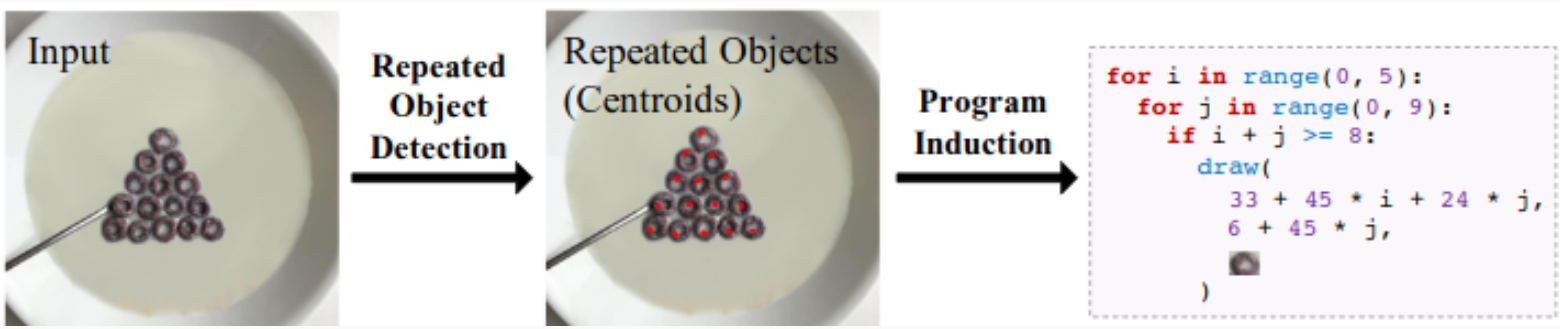
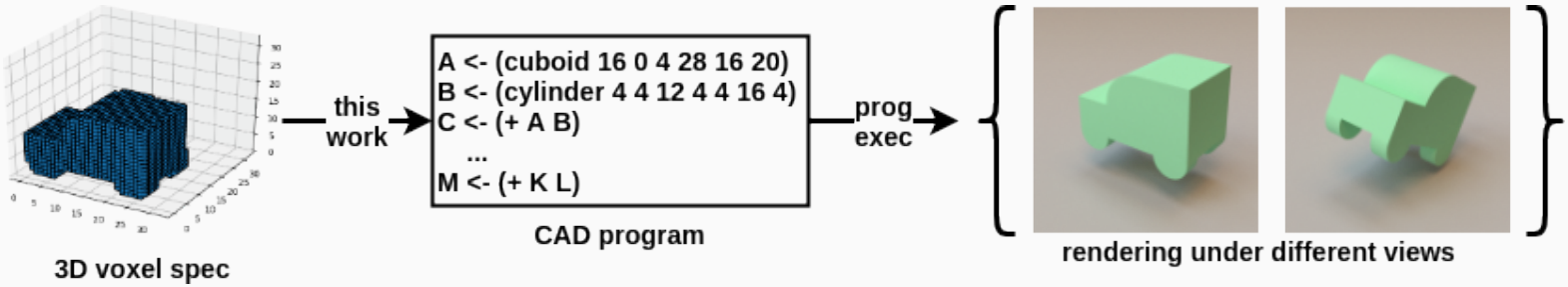
(b) Caddy program

op	::=	+ | - | × | /
num	::=	$\mathbb{R}$ | ⟨*var*⟩ | ⟨*num*⟩ ⟨*op*⟩ ⟨*num*⟩
vec2	::=	[⟨*num*⟩, ⟨*num*⟩]
vec3	::=	[⟨*num*⟩, ⟨*num*⟩, ⟨*num*⟩]
affine	::=	Translate | Rotate | Scale | **TranslateSpherical**
binop	::=	Union | Difference | Intersection
cad	::=	(Cuboid ⟨*vec3*⟩) | (Sphere ⟨*num*⟩)
	|	(Cylinder ⟨*vec2*⟩) | (HexPrism ⟨*vec2*⟩) | …
	|	(⟨*affine*⟩ ⟨*vec3*⟩ ⟨*cad*⟩)
	|	(⟨*binop*⟩ ⟨*cad*⟩ ⟨*cad*⟩)
	|	**(Fold** ⟨*binop*⟩ ⟨*cad-list*⟩**)**
cad-list	::=	(List ⟨*cad*⟩+)
	|	(Concat ⟨*cad-list*⟩+)
	|	(Tabulate (⟨*var*⟩ $\mathbb{Z}^+$)+ ⟨*cad*⟩)
	|	(Map2 ⟨*affine*⟩ ⟨*vec3-list*⟩ ⟨*cad-list*⟩)
vec3-list	::=	(List ⟨*vec3*⟩+)
	|	(Concat ⟨*vec3-list*⟩+)
	|	(Tabulate (⟨*var*⟩ $\mathbb{Z}^+$)+ ⟨*vec3*⟩)

Visual programs



Mao*, Zhang*, et al 2019



Ellis*, Nye*, Pu*, Sosa*, et al 2019

partial image x_{part}

```
for i = 1..3
  for j = 1..1
    draw(i*2, j*1, )
      ...
```

synthesized program P_{part}

Young et al 2019

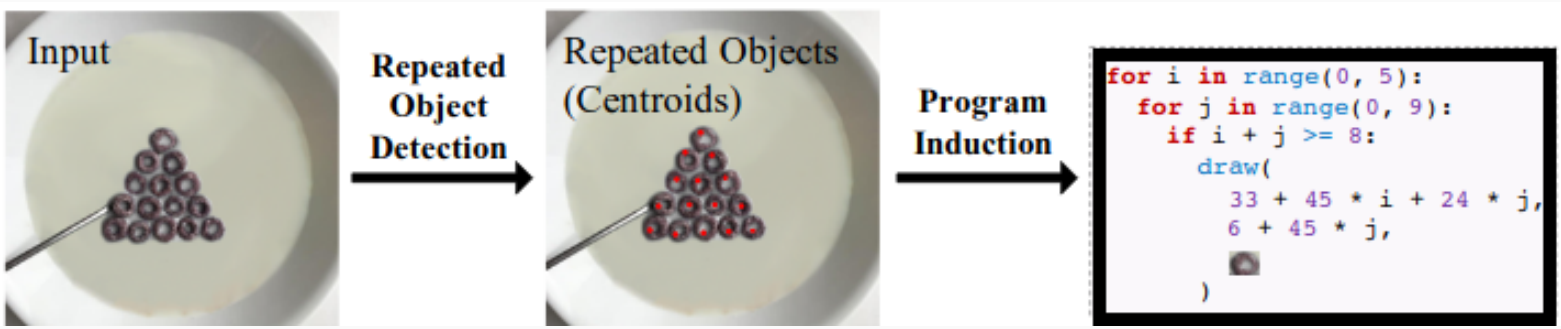
```
Draw("Top", "Circle", position, geometry)

for(i < 2, "translation", a)
  for(j < 2, "translation", b)
    Draw("Leg", "Cub", position + i*a + j*b, g

for(i < 2, "translation", c)
  Draw("Layer", "Rec", position + i*c, geomet
```

Tian et al 2019

Where does this language come from?



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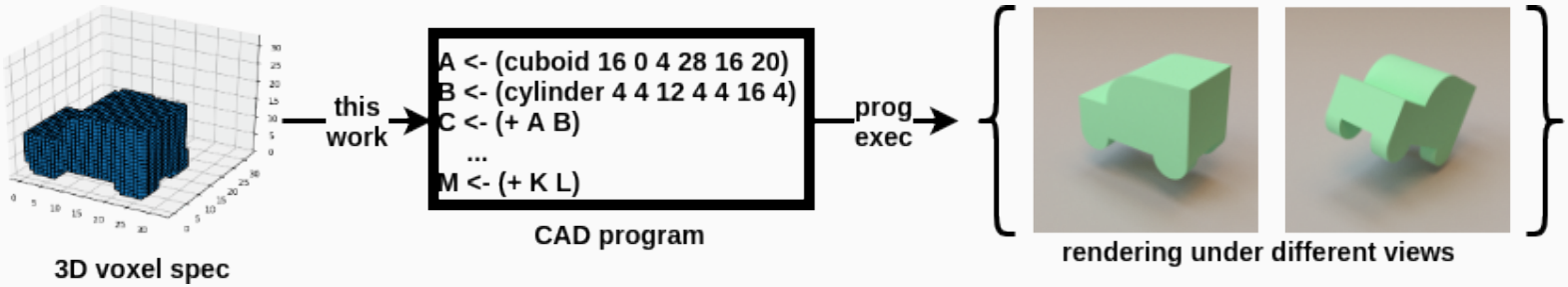

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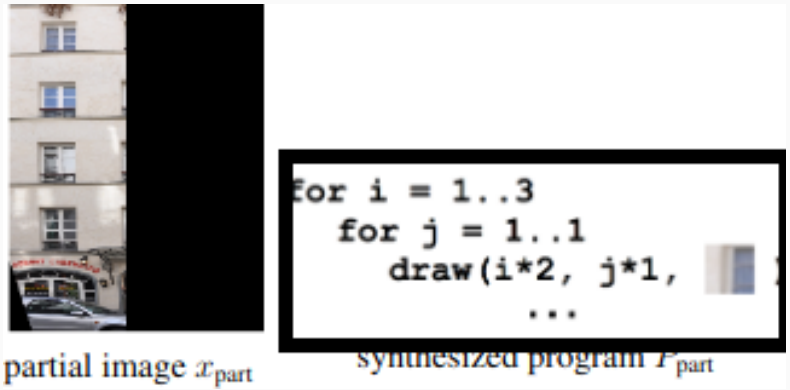

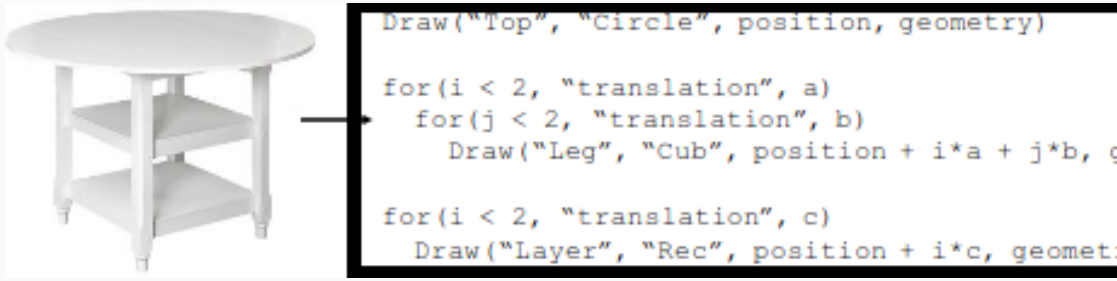

Young et al 2019

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Program Induction and learning to learn

learning a DSL

learning to synthesize

synergy between DSL+learned synthesizer

Learning to write code

Goal: acquire domain-specific knowledge needed to induce a class of programs

- Library of abstractions (domain specific language)
- Inference strategy (synthesis algorithm)

Library learning

Initial Primitives

```
map
fold
if
cons
>
```

Sample Problem: `sort list`

[9 2 7 1] → [1 2 7 9]
[3 8 9 4 2] → [2 3 4 8 9]
[6 2 2 3 8 5] → [2 2 3 5 6 8]
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Ellis, Morales, Sable-Meyer, Solar-Lezama, Tenenbaum. NeurIPS 2018.

Ellis, Wong, Nye, ..., Solar-Lezama, Tenenbaum. arxiv 2020.

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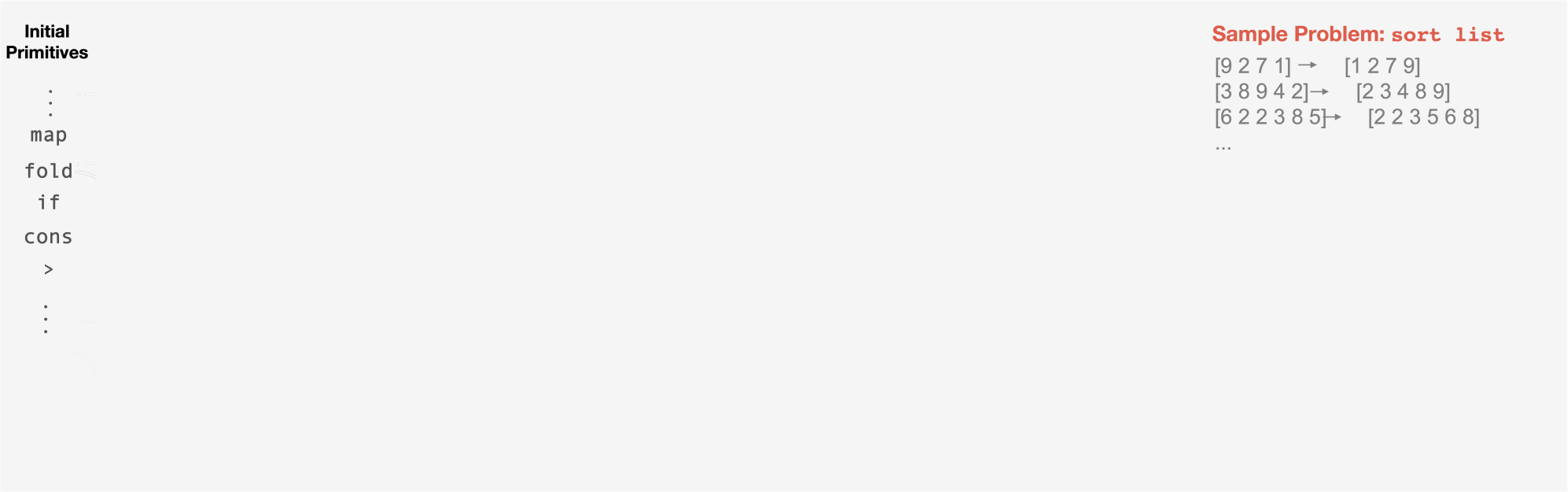

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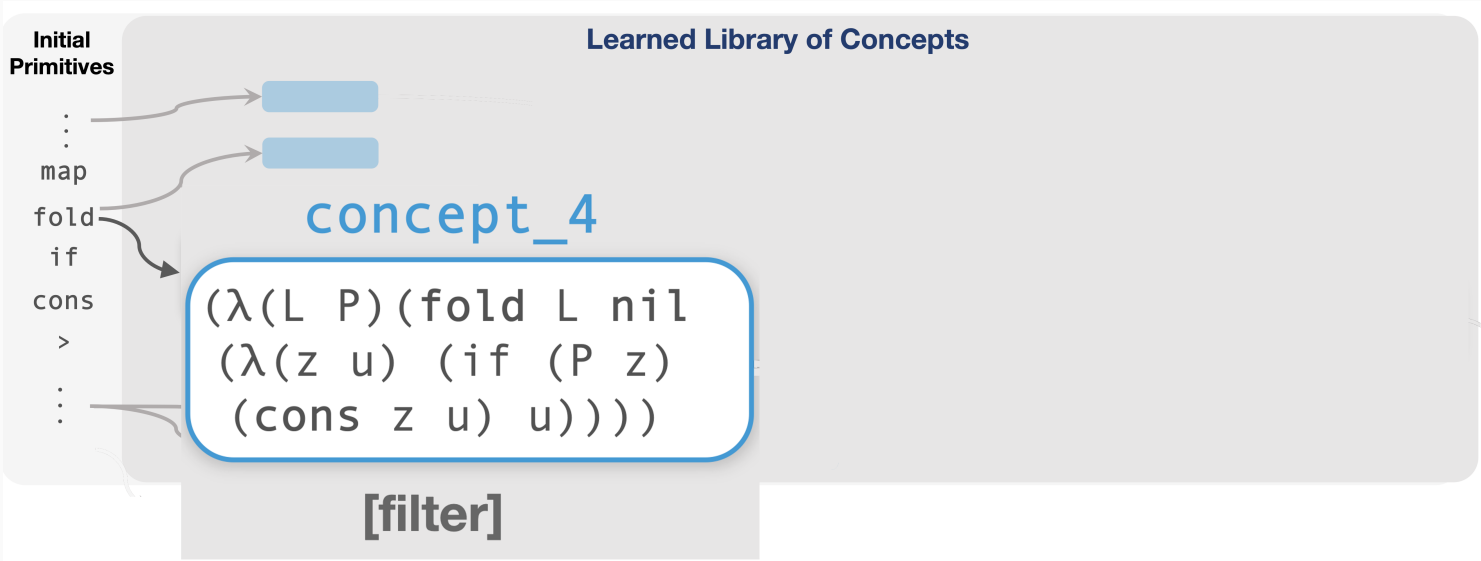

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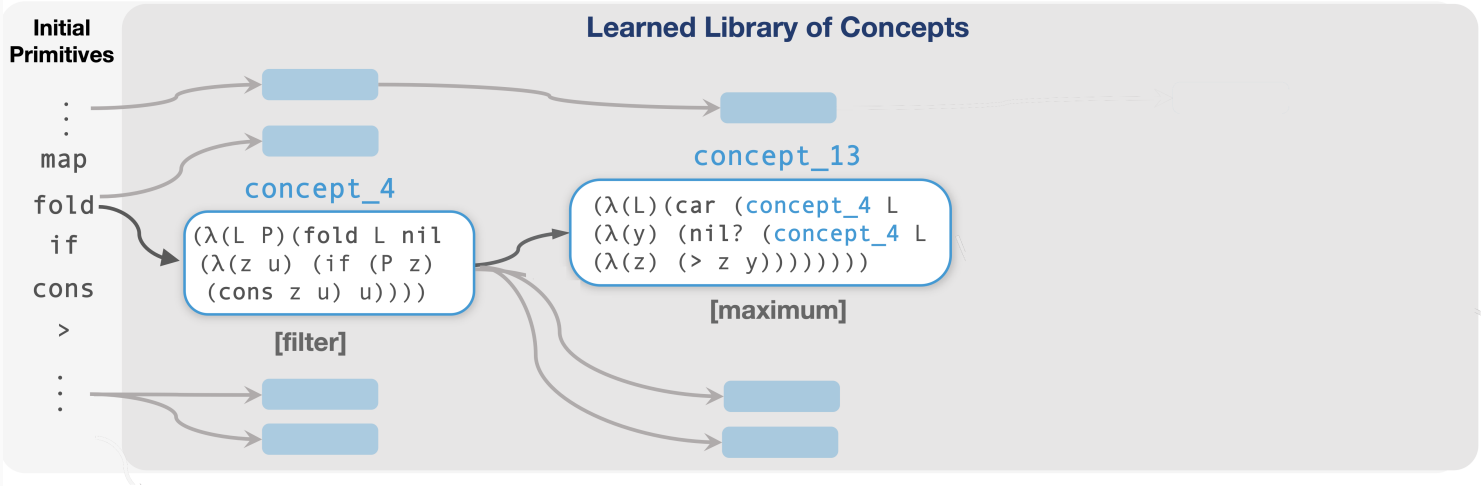

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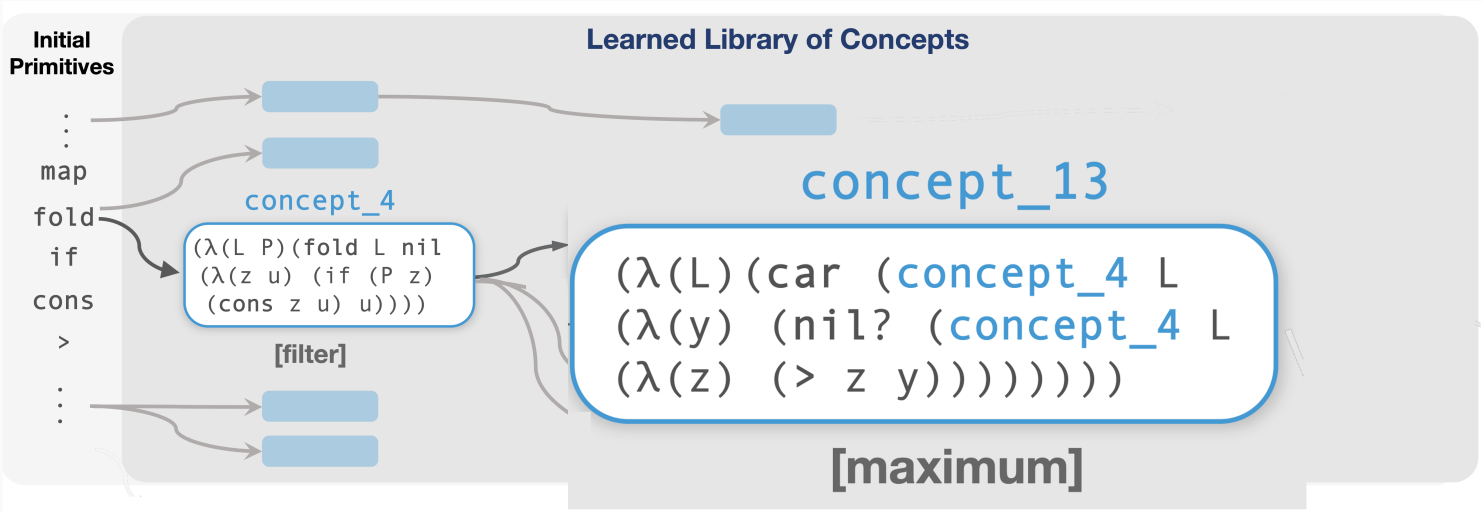

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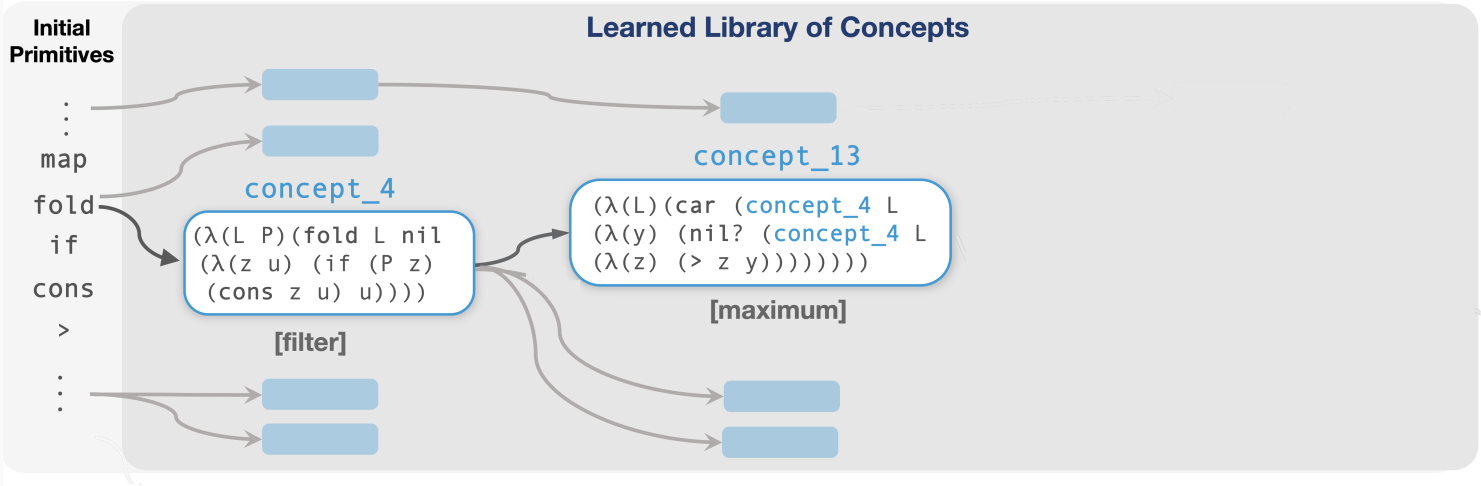

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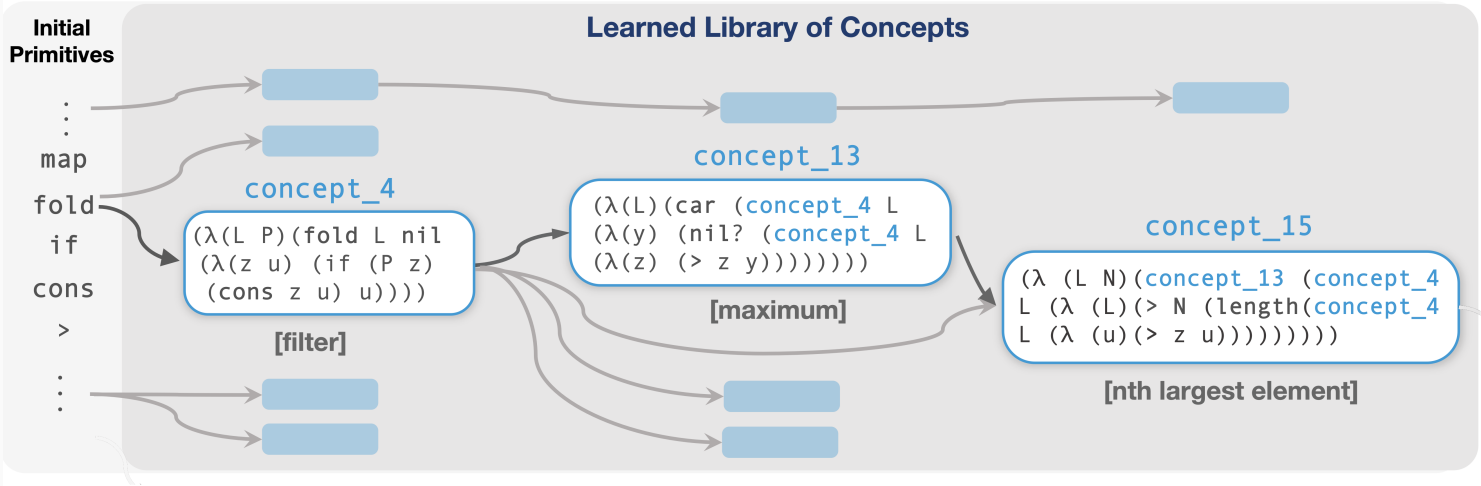

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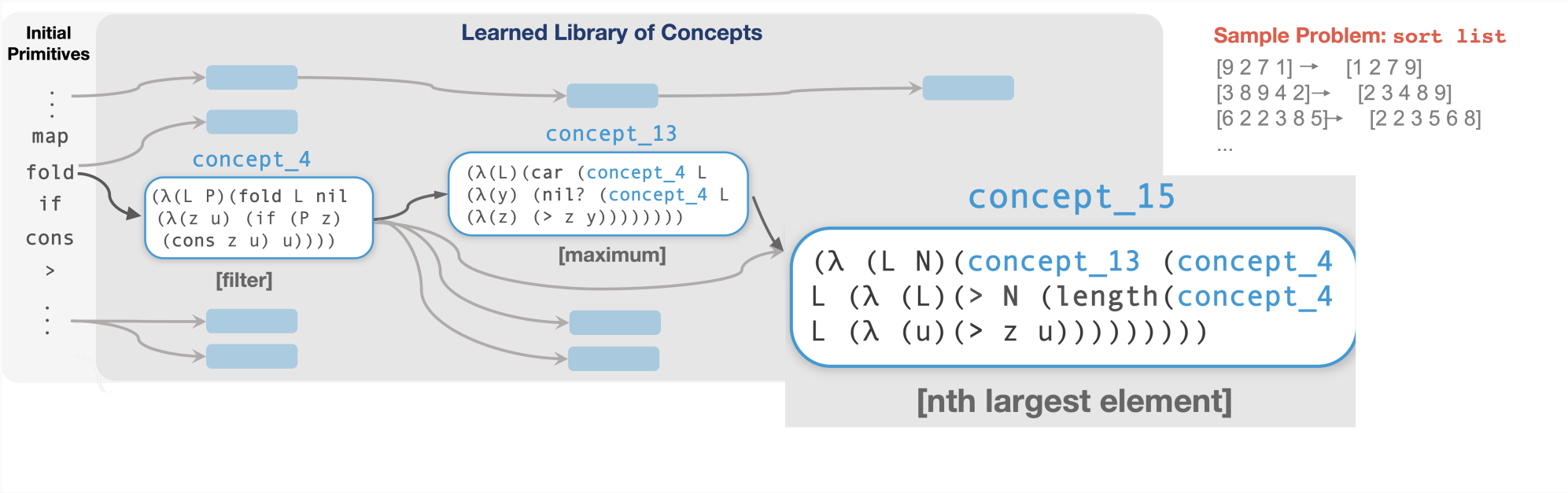

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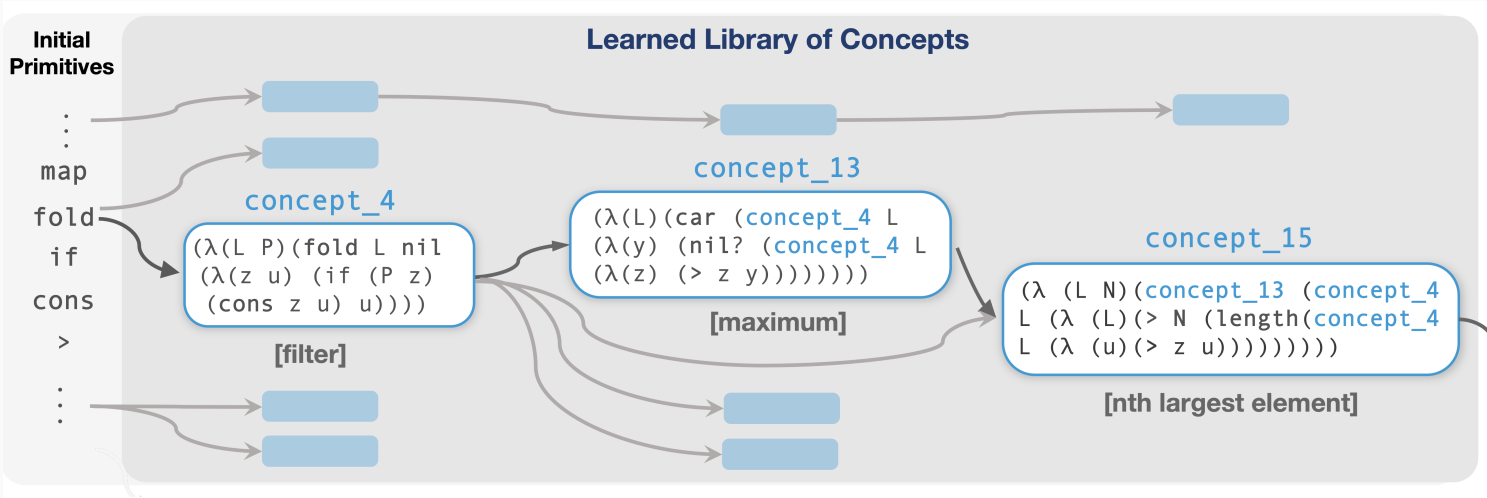

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Solution to `sort list` discovered in learned language:

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(map  (λ (n)
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Ellis, Wong, Nye, ..., Solar-Lezama, Tenenbaum. arxiv 2020.

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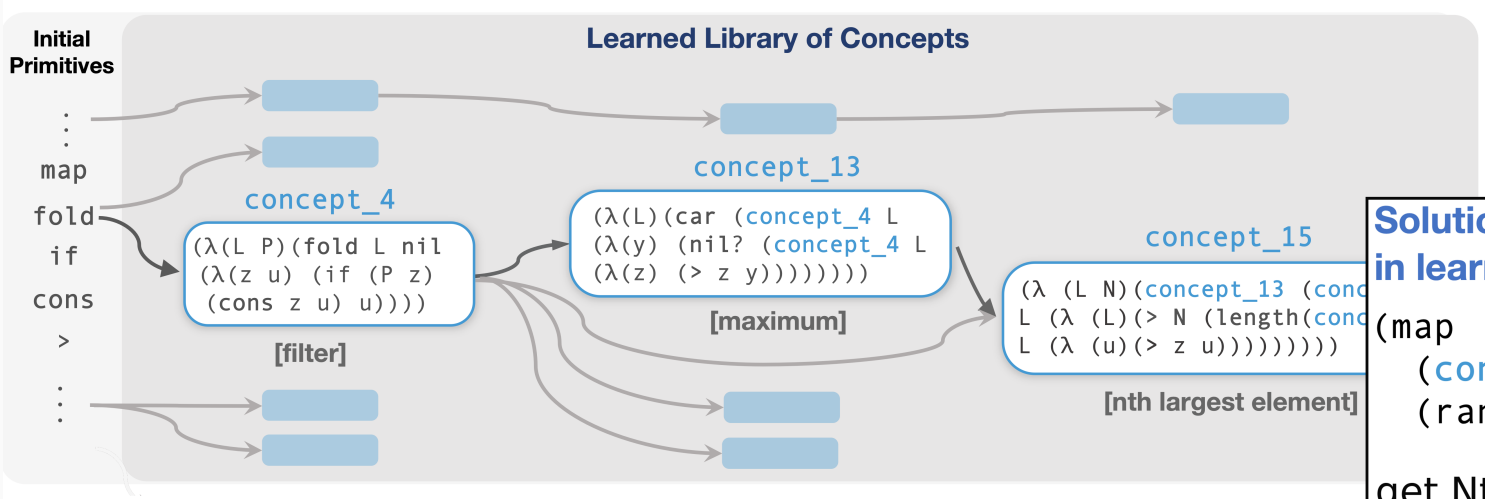

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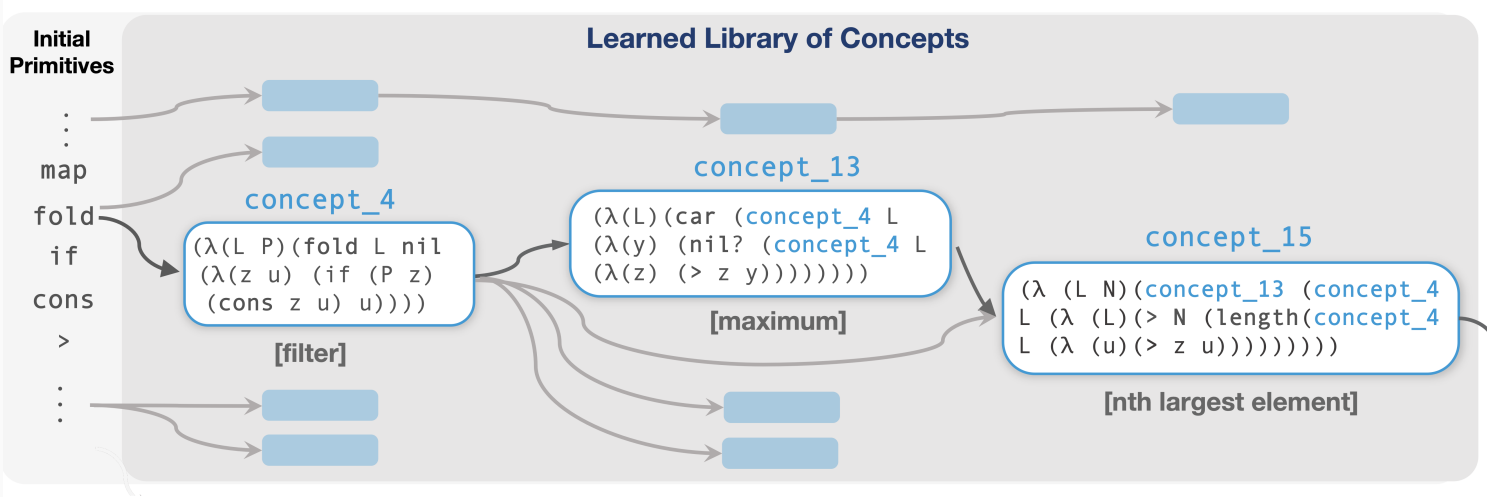

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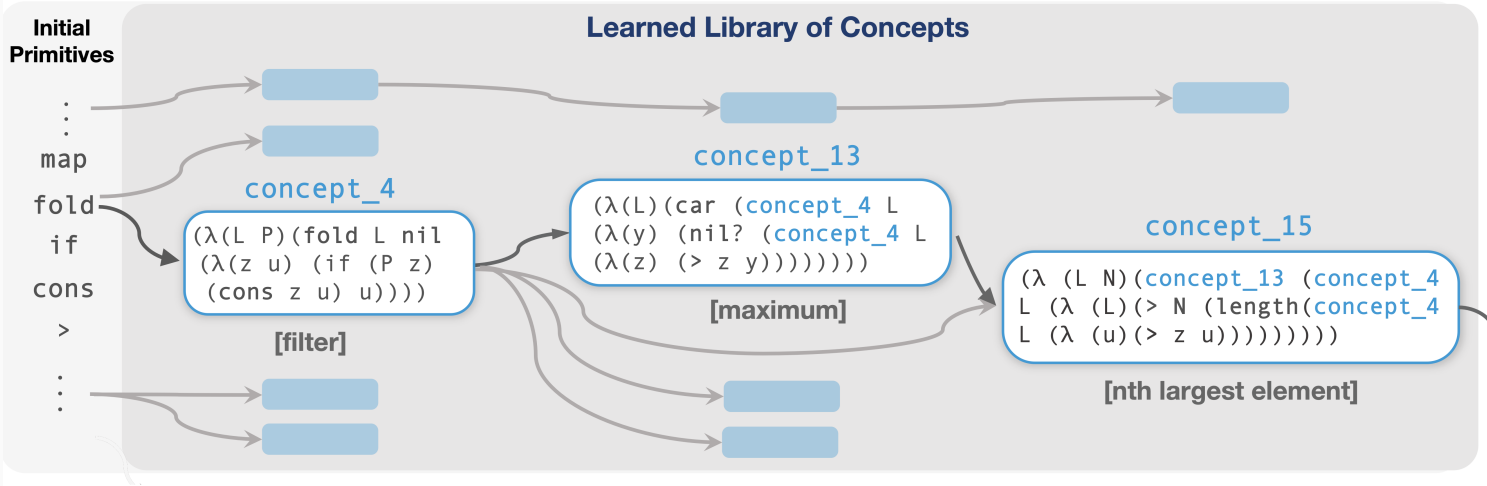

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induced sort program found in $\leq$ 10min. Brute-force search without learned library would take $\approx 10^{73}$ years

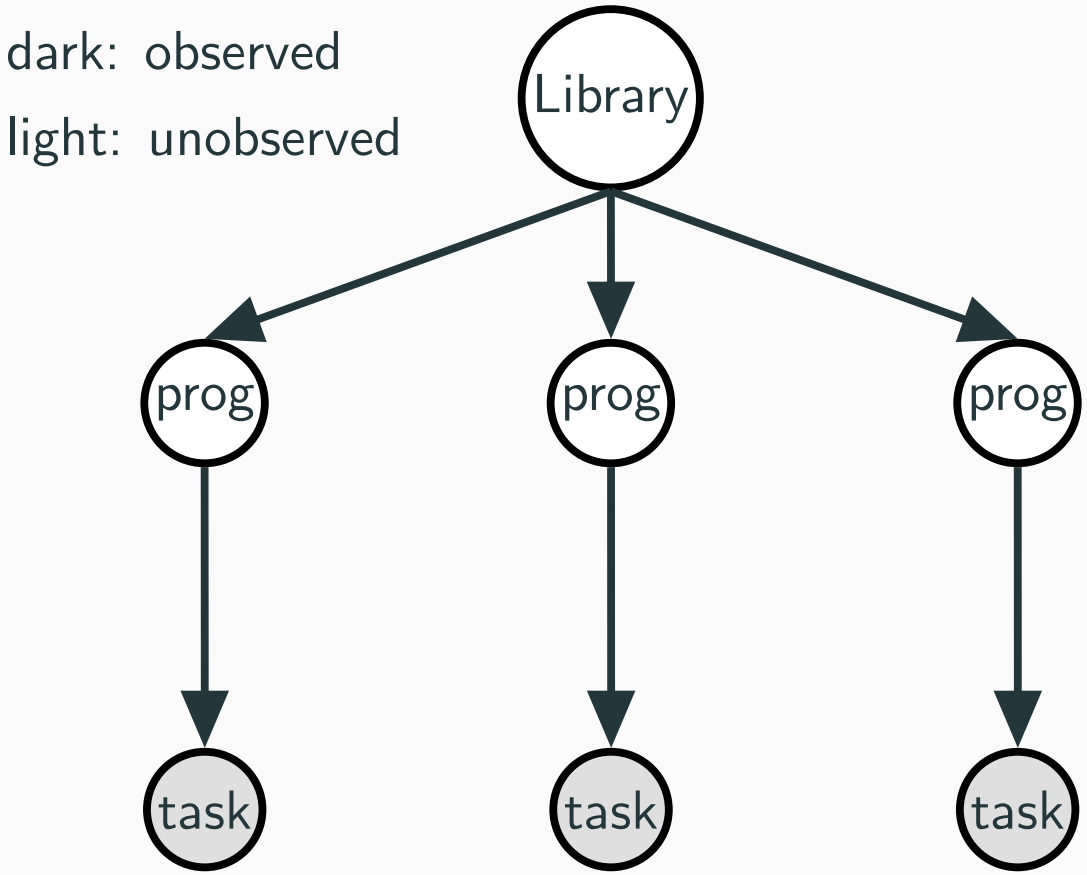
Ellis, Wong, Nye, ..., Solar-Lezama, Tenenbaum. arxiv 2020.

DreamCoder

- **Wake:** Solve problems by writing programs
- **Sleep:** Improve library and neural recognition model:
  - **Abstraction sleep:** Improve library
  - **Dream sleep:** Improve neural recognition model

cf. Helmholtz machine, wake/sleep neural network training algorithms

Library learning as Bayesian inference



[Dechter et al, 2013] [Liang et al, 2010] [Lake et al, 2015]

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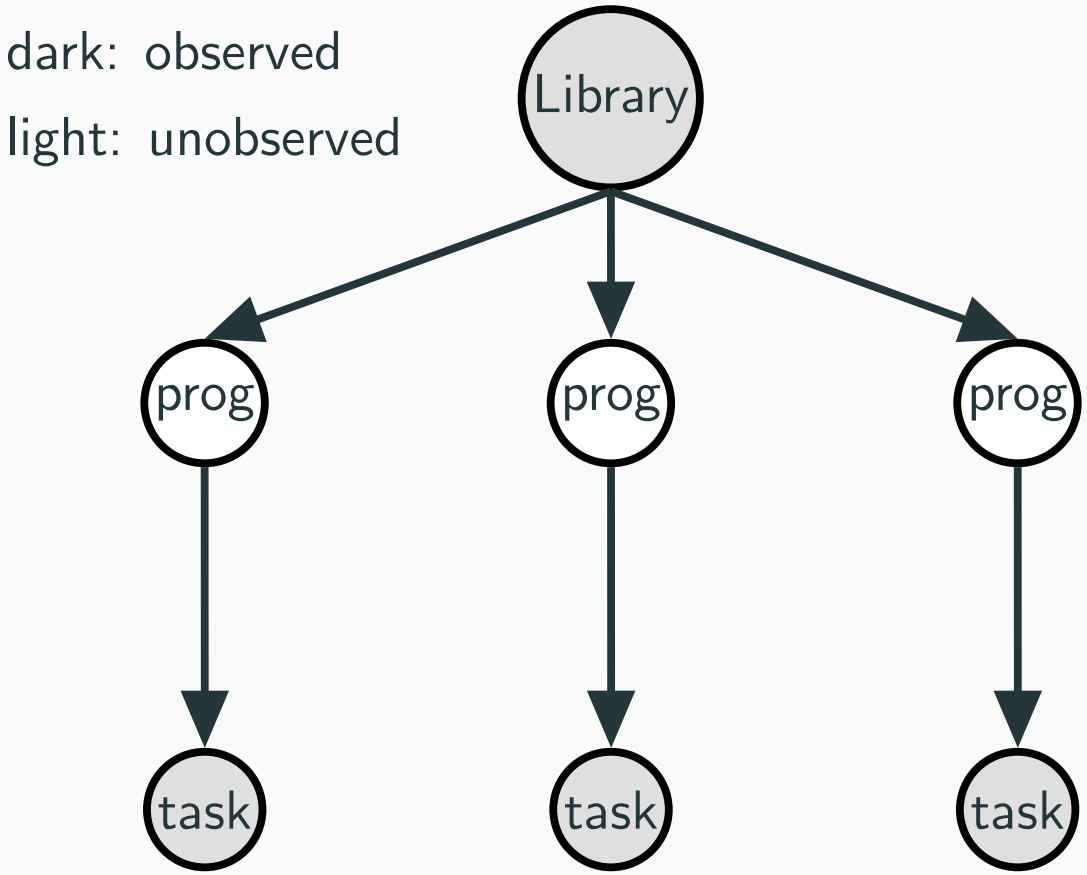

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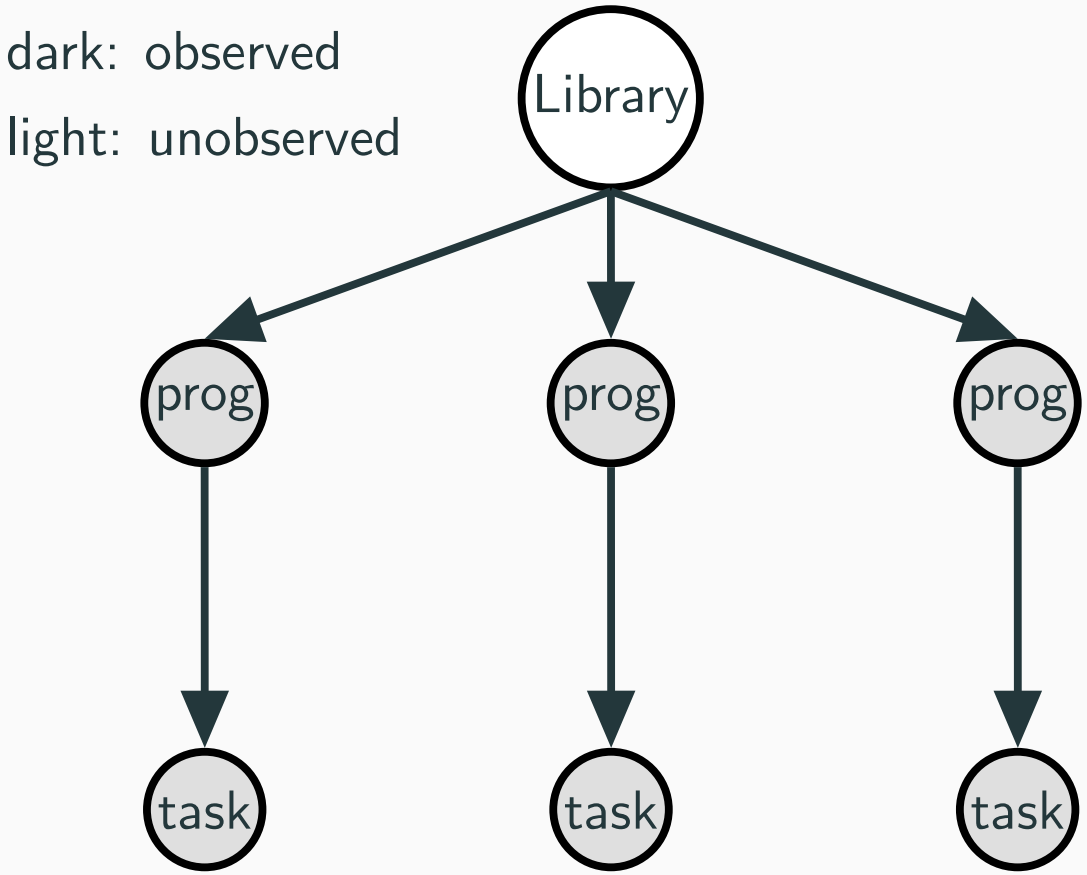
Library learning as Bayesian inference



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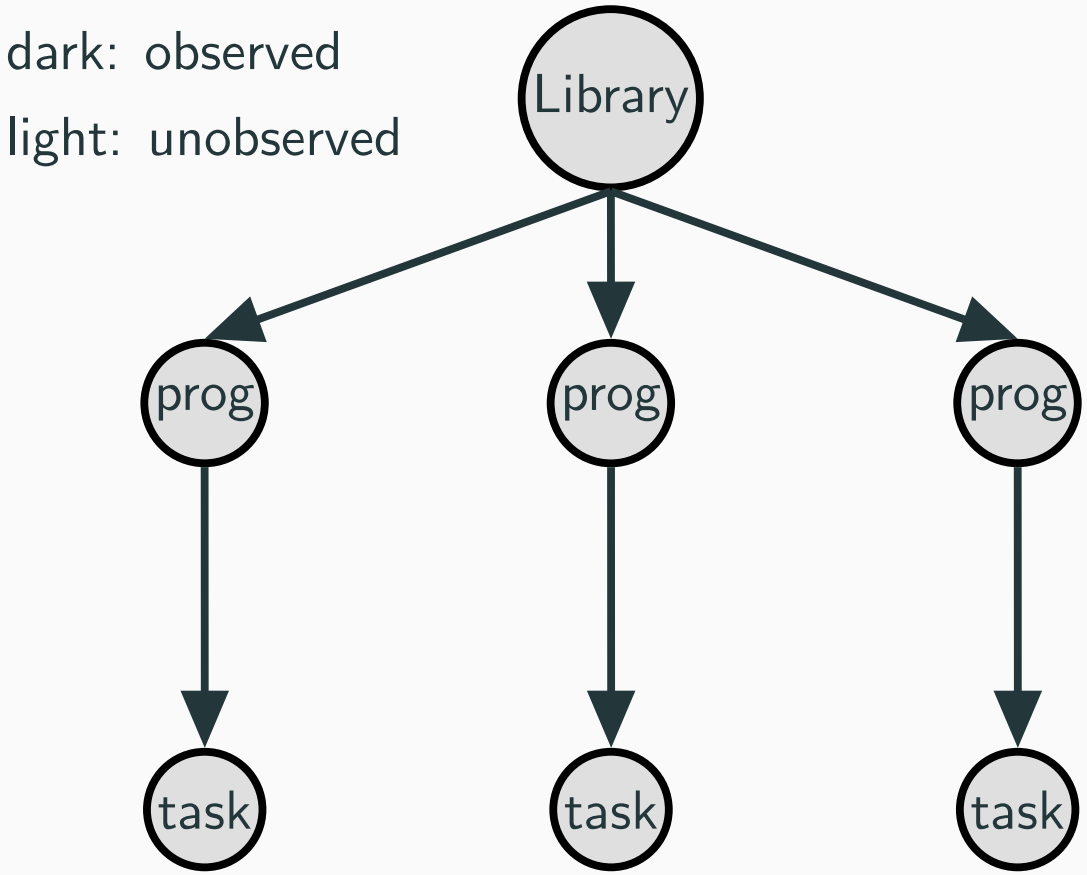

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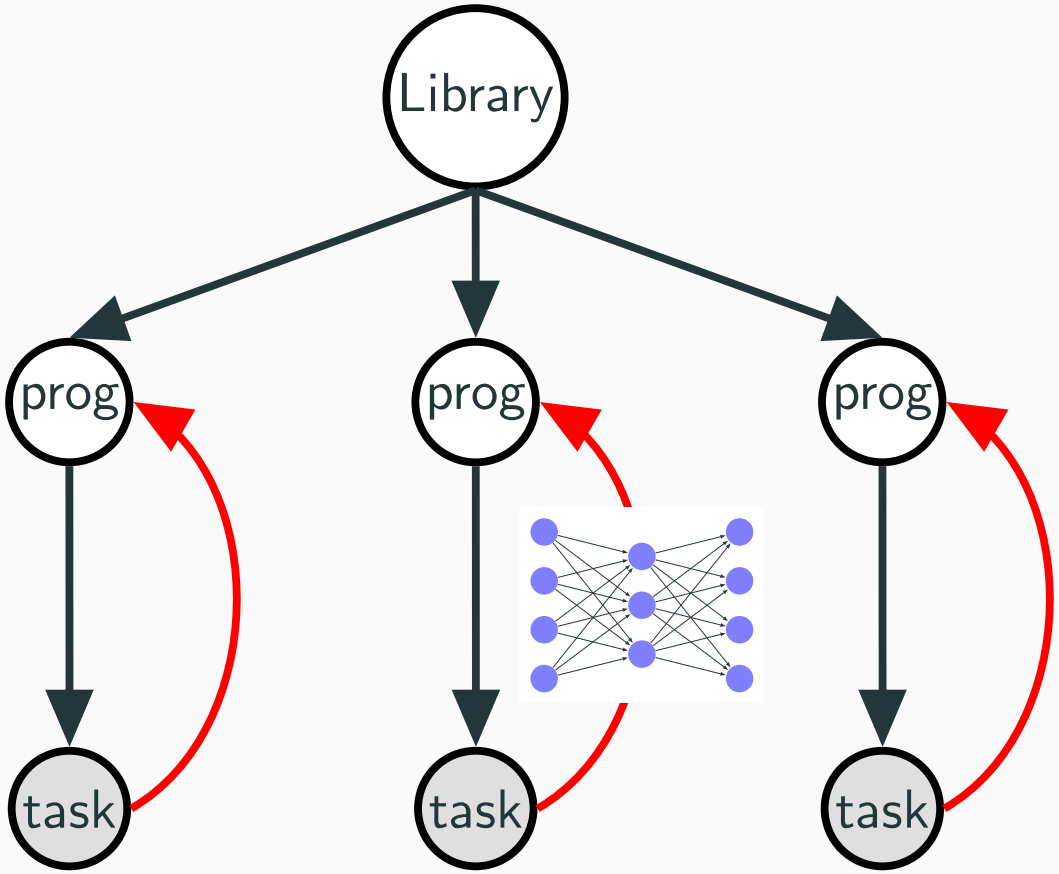
Library learning as neurally-guided Bayesian inference

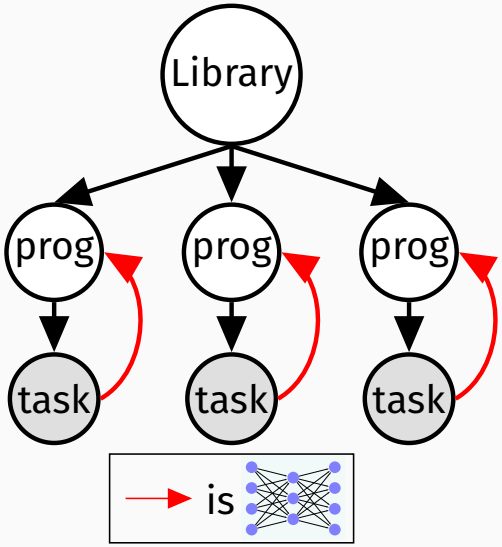


library learning via program analysis +

new neural inference network for program synthesis +

better program representation (Lisp+polymorphic types [Milner 1978])

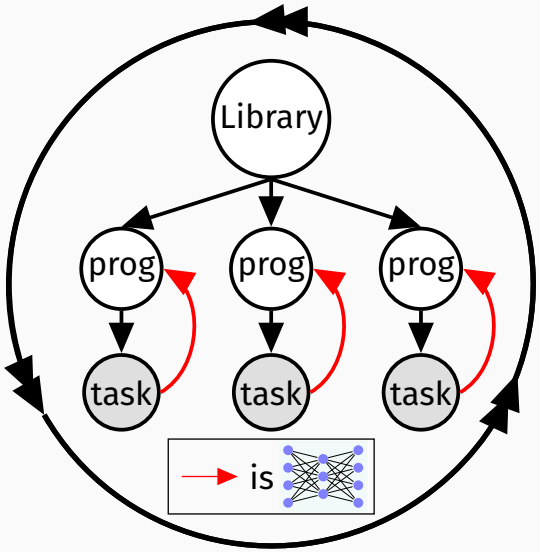
Ellis, Wong, Nye, ..., Solar-Lezama, Tenenbaum. arxiv 2020.


Library
prog
prog
prog
task
task
task
is

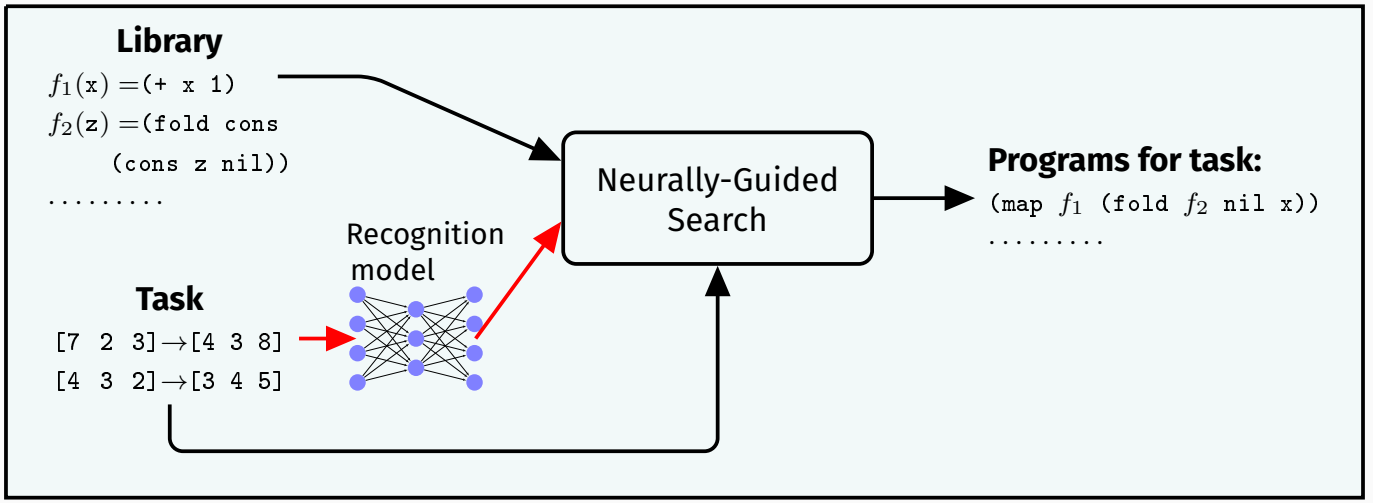
Wake

Sleep: Abstraction

Sleep: Dreaming



Wake



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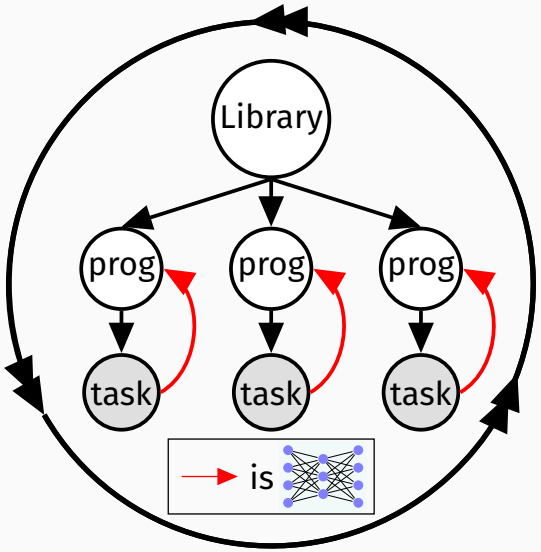

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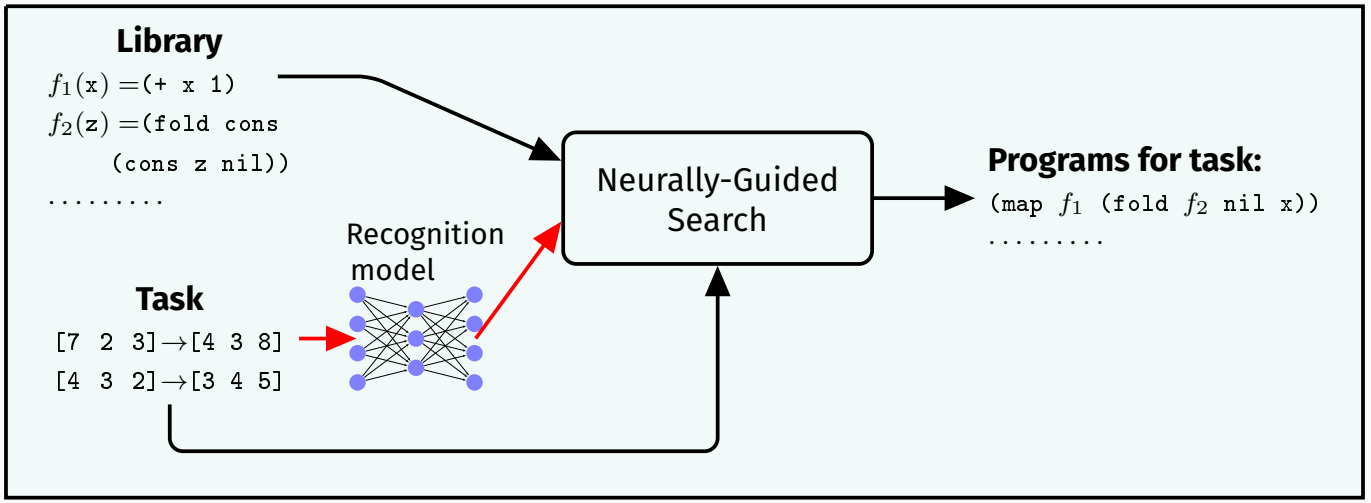

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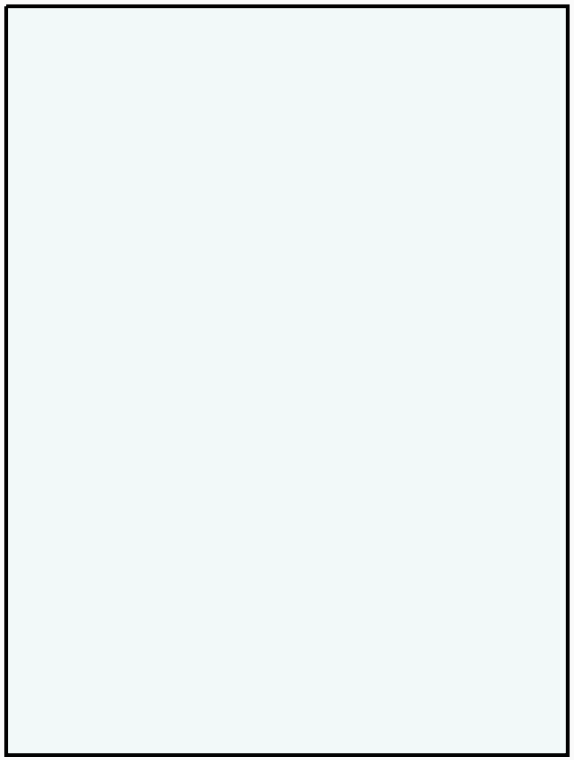

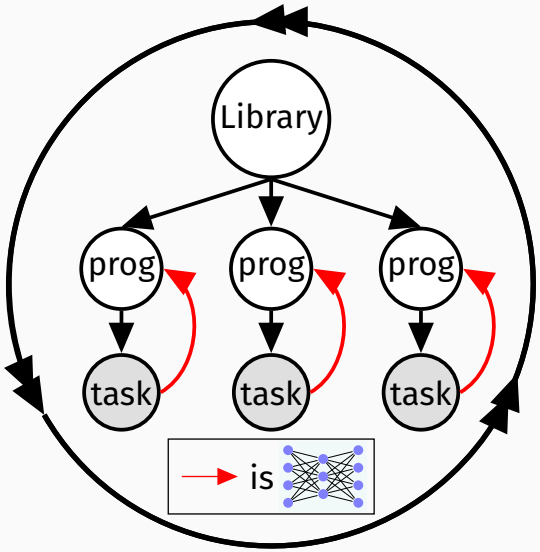

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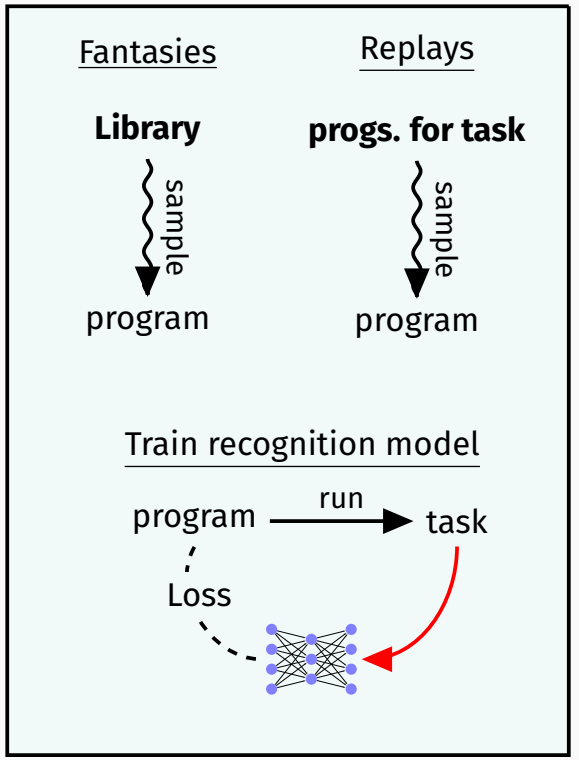

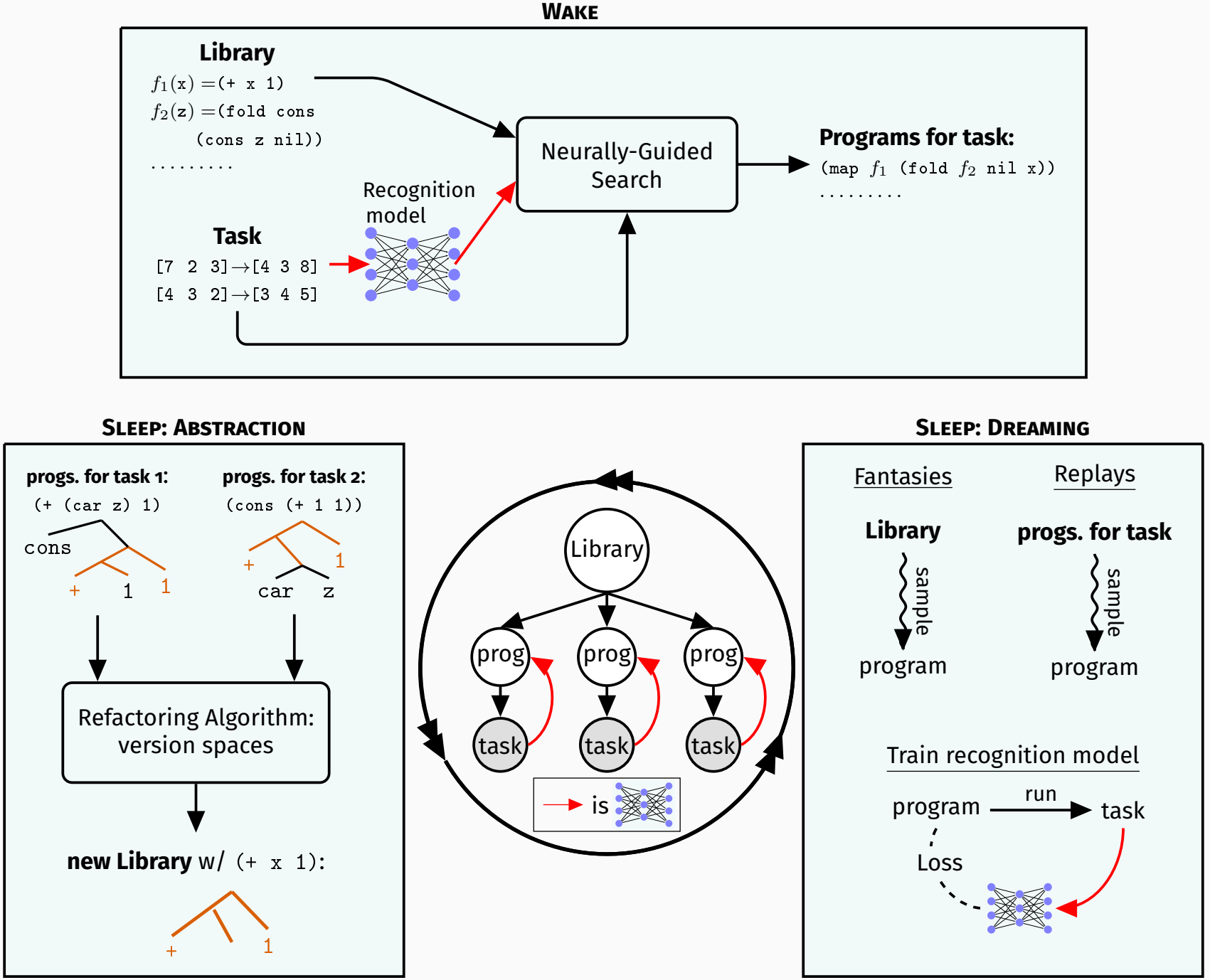
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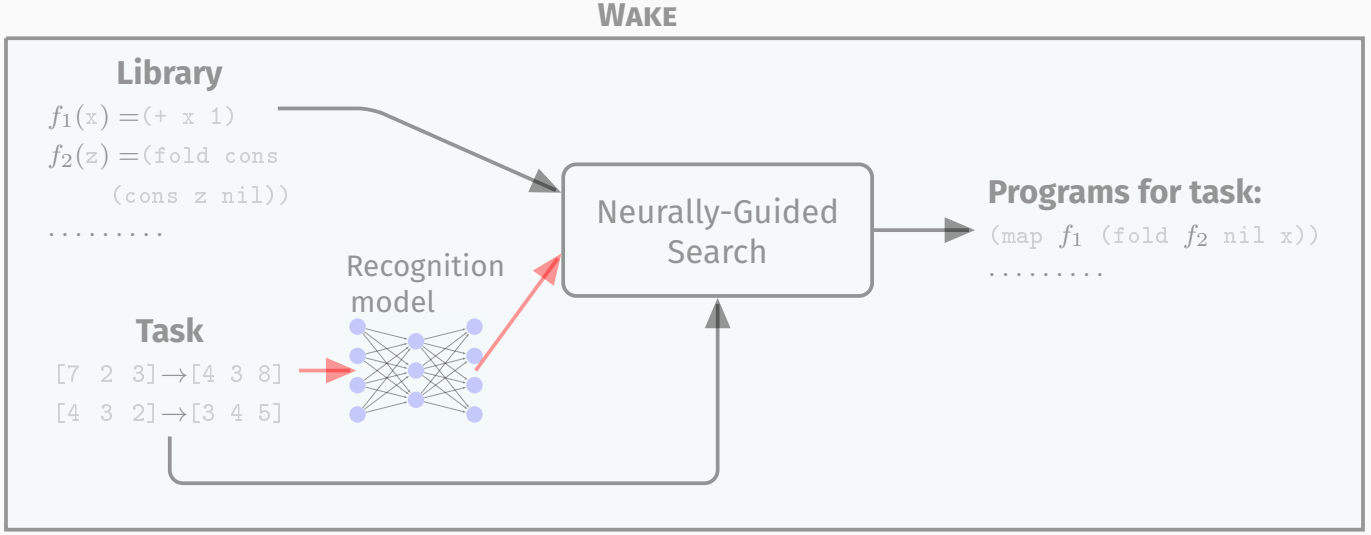
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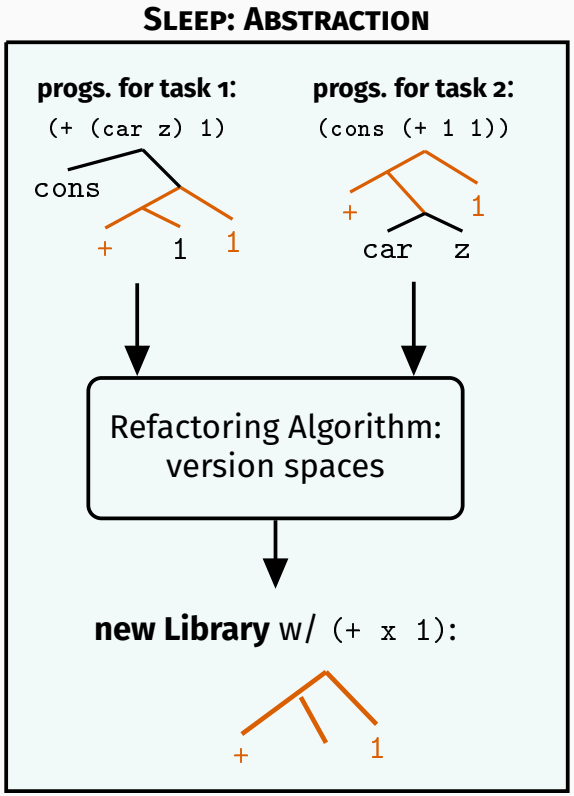
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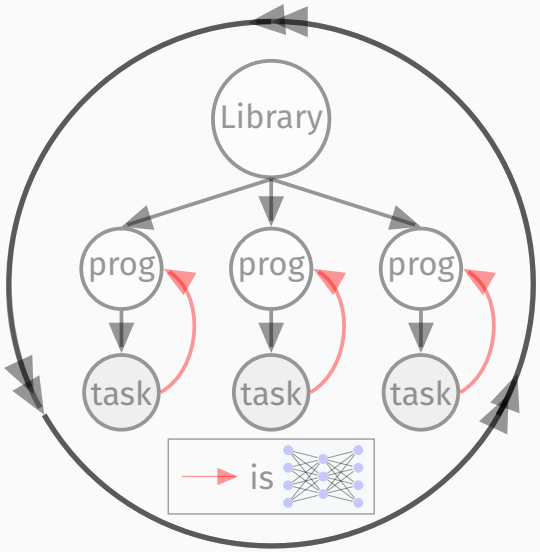
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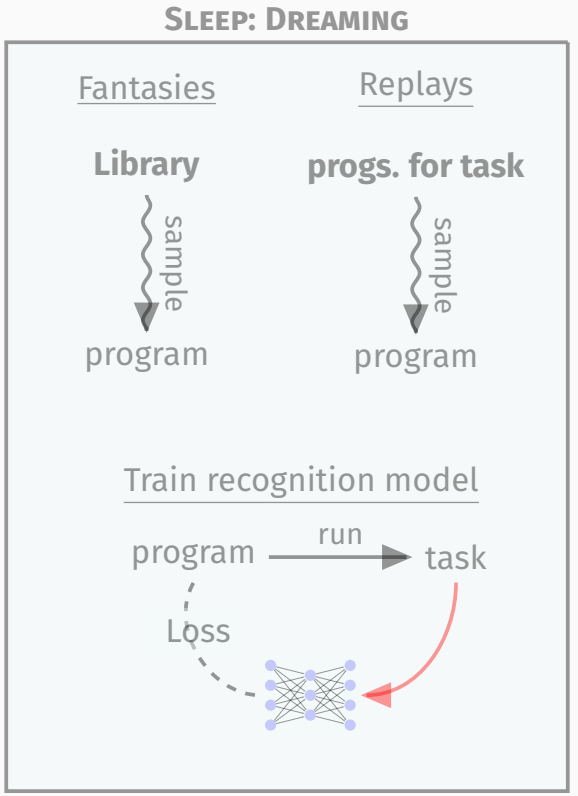
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Program Induction and learning to learn

learning a DSL

learning to synthesize

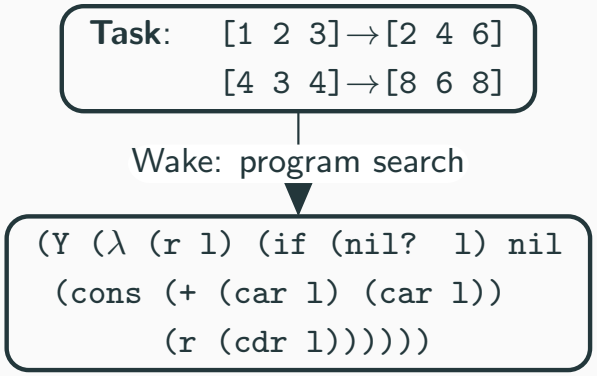
synergy between DSL+learned synthesizer

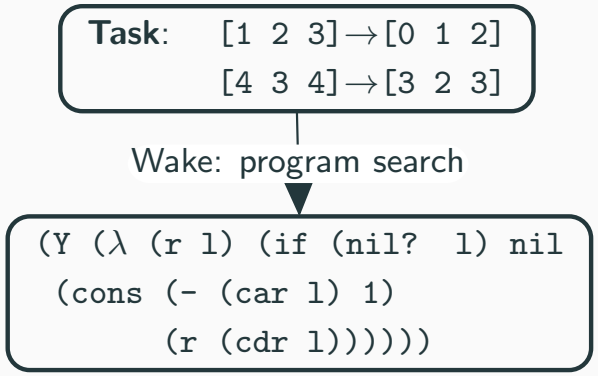
Abstraction Sleep: Growing the library via refactoring

Task: [1 2 3]→[2 4 6]
[4 3 4]→[8 6 8]

Task: [1 2 3]→[0 1 2]
[4 3 4]→[3 2 3]

Abstraction Sleep: Growing the library via refactoring





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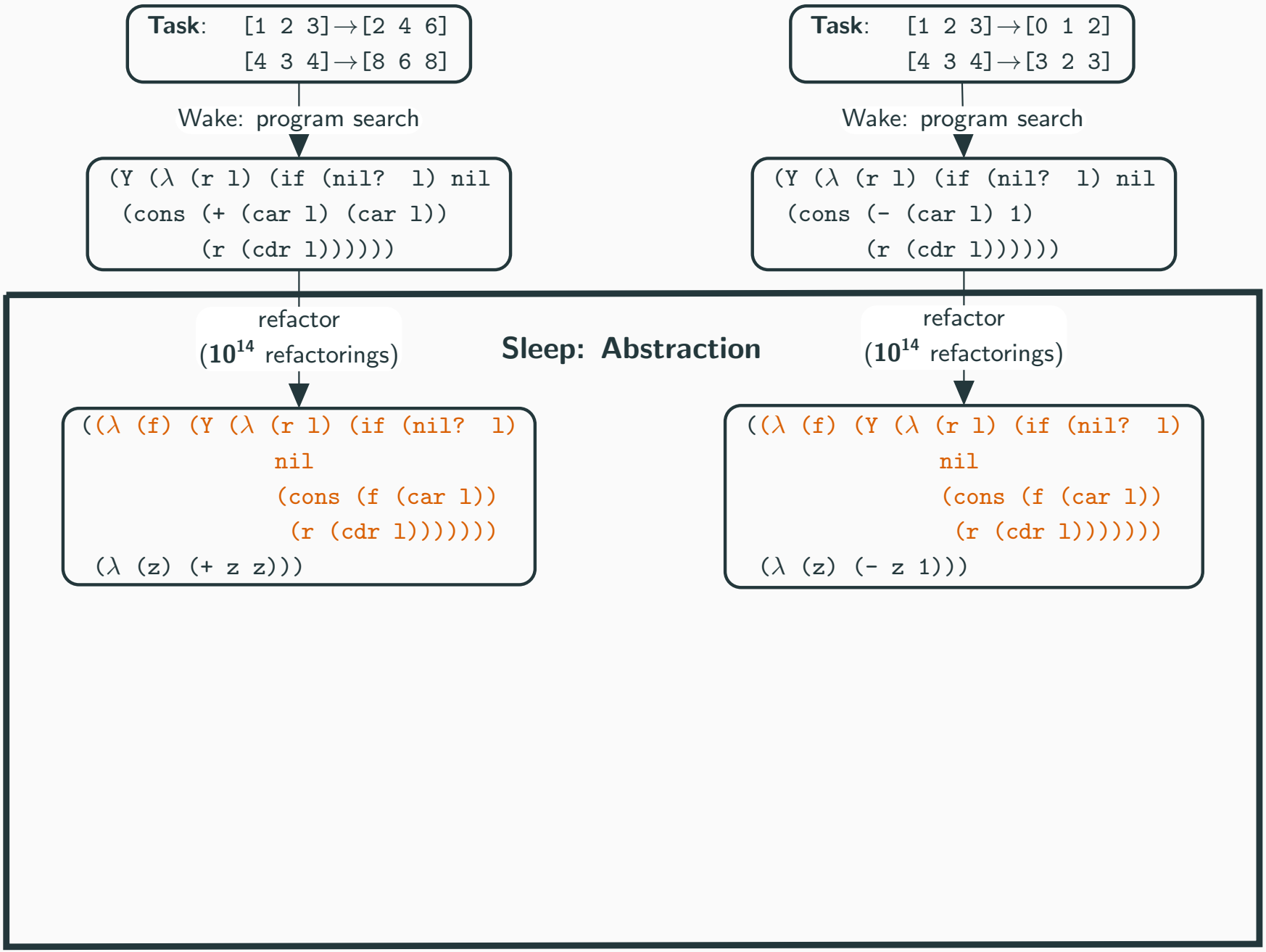

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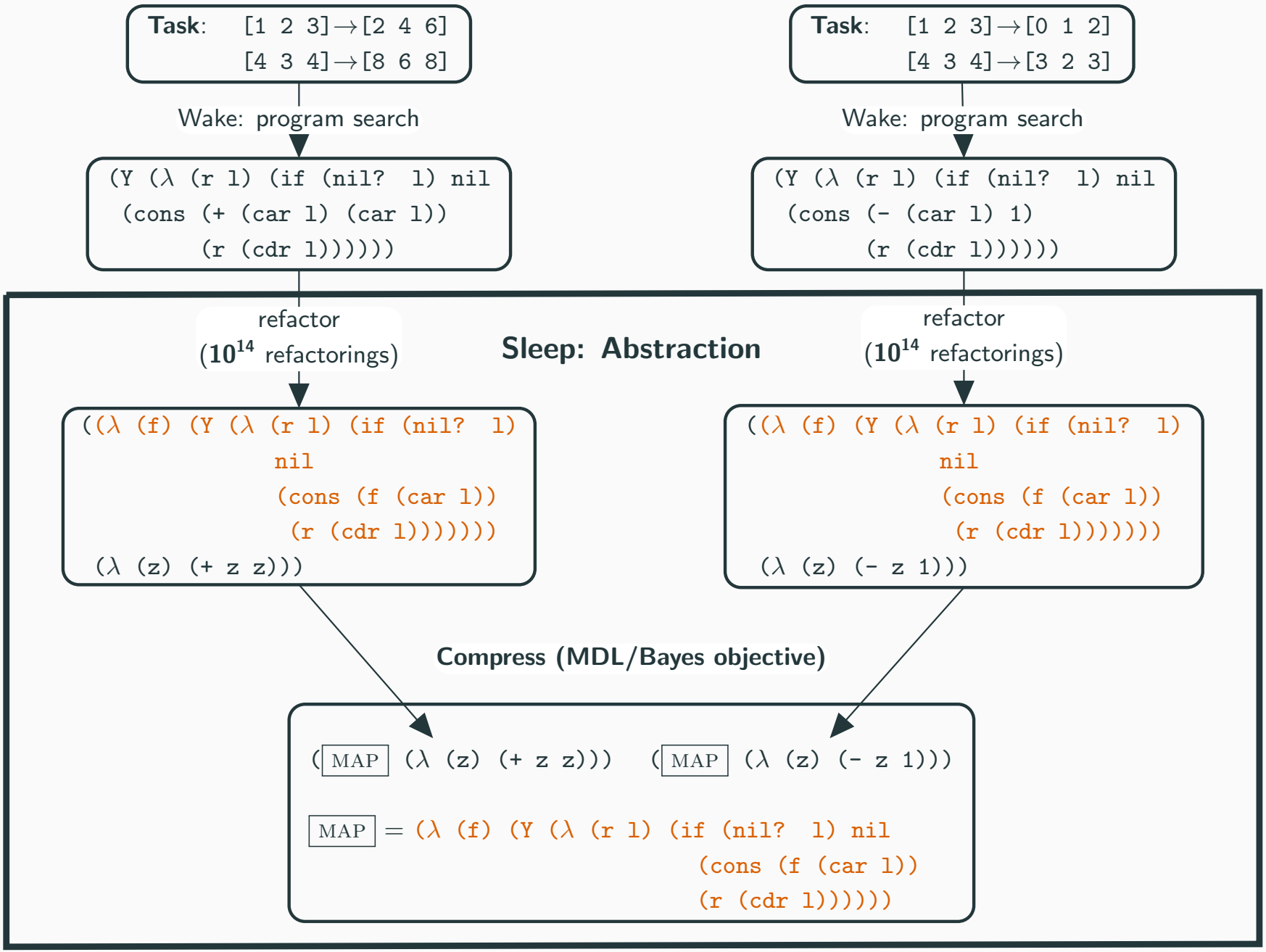

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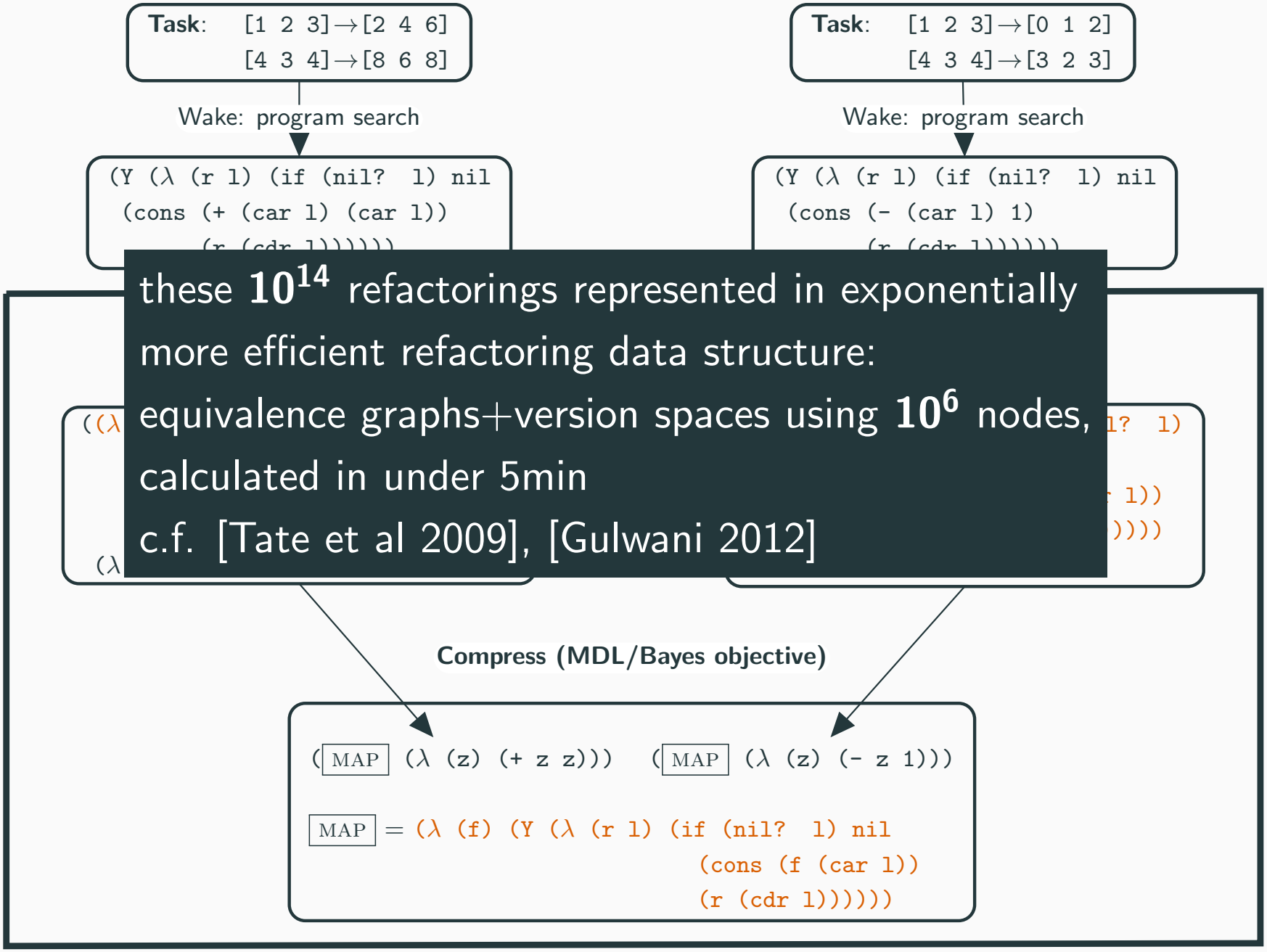

Program Induction and learning to learn

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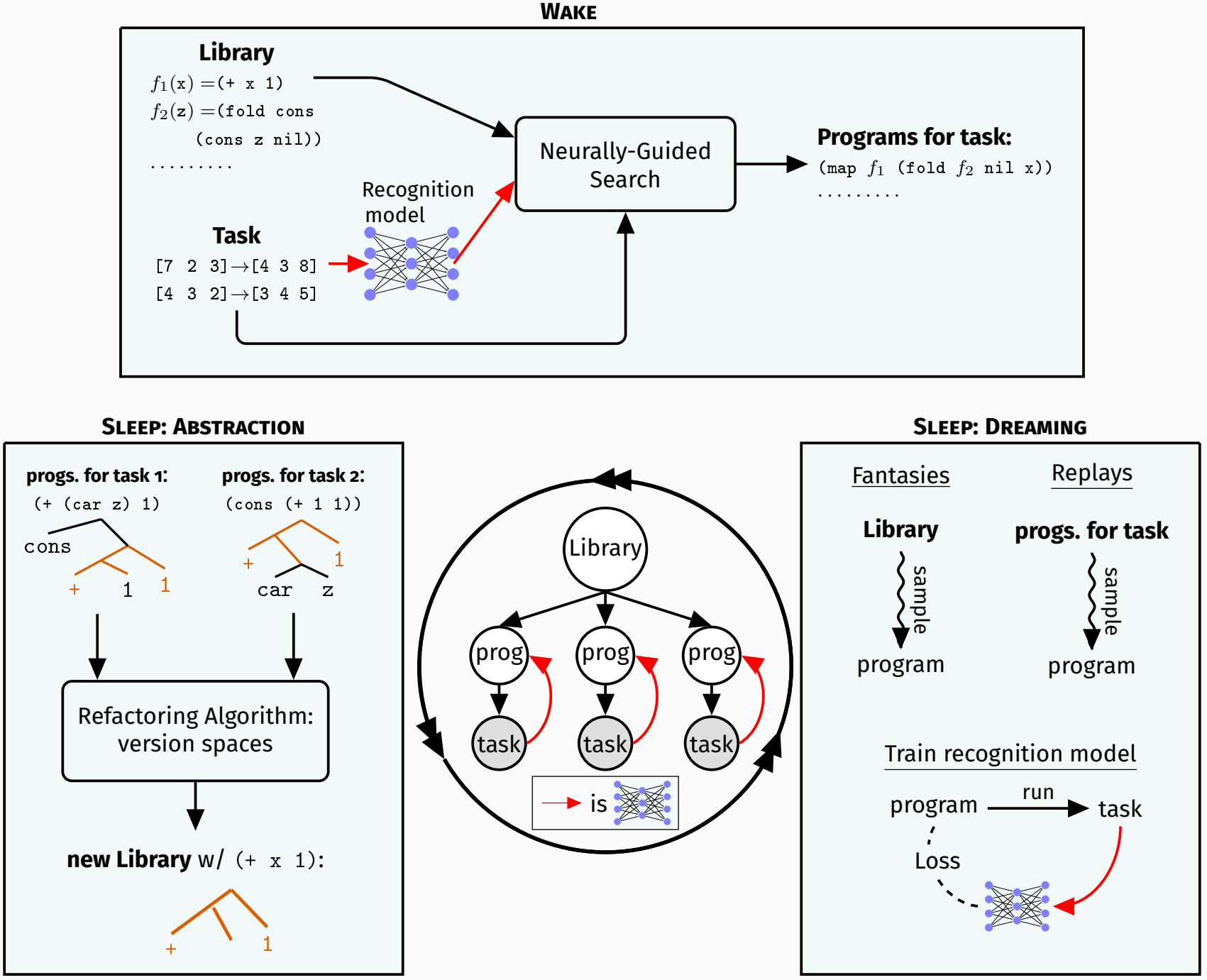
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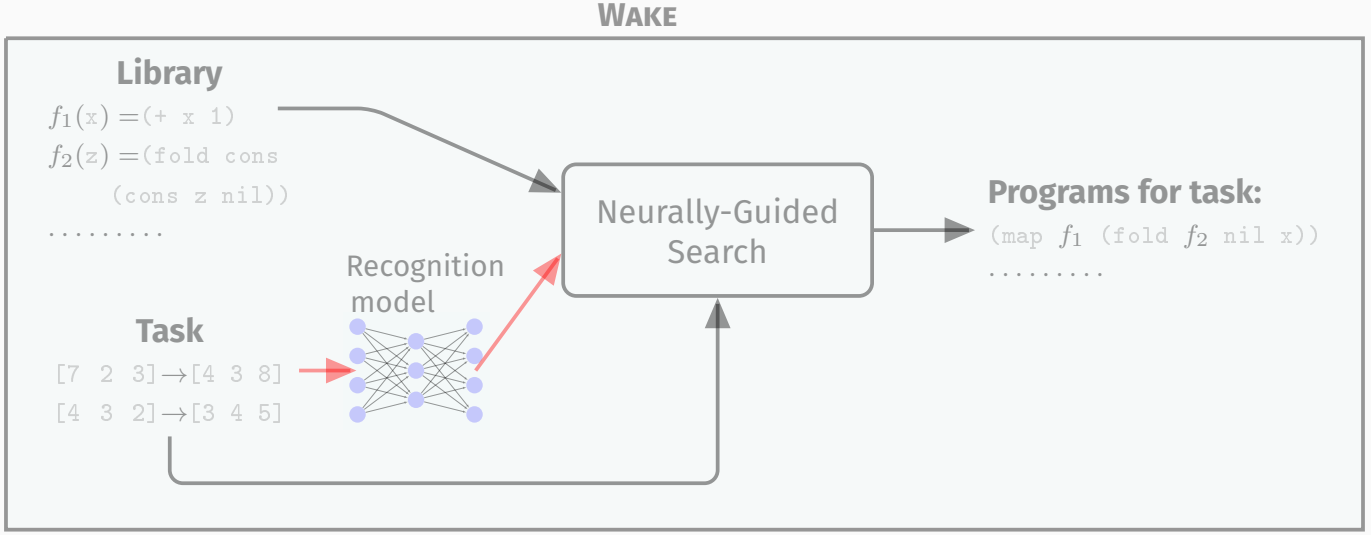
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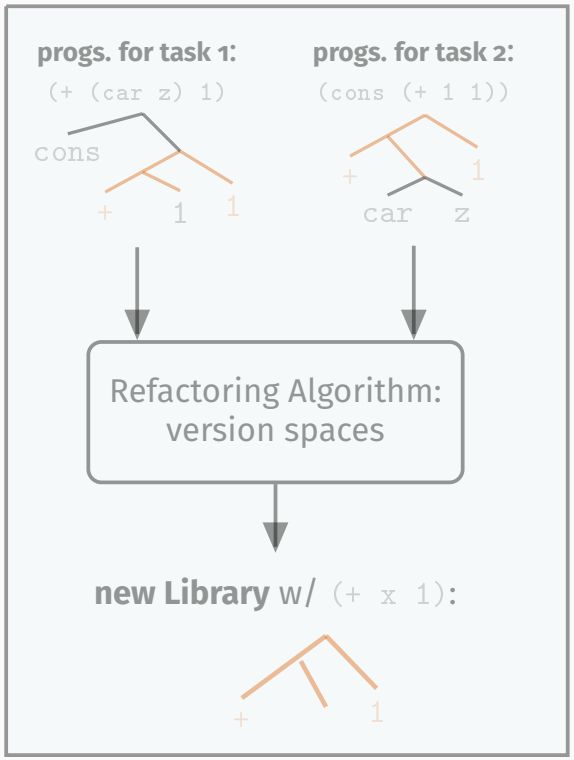
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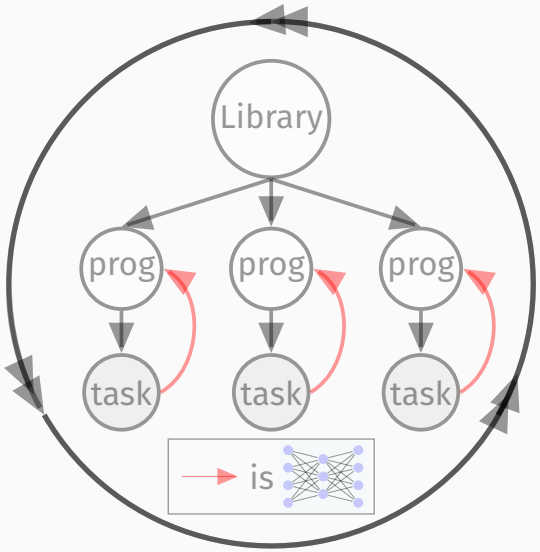
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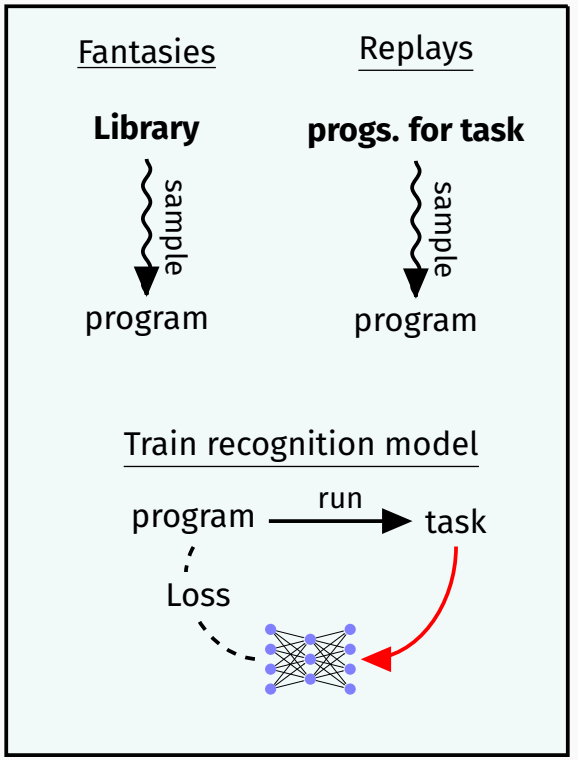
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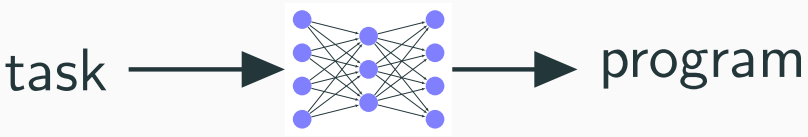

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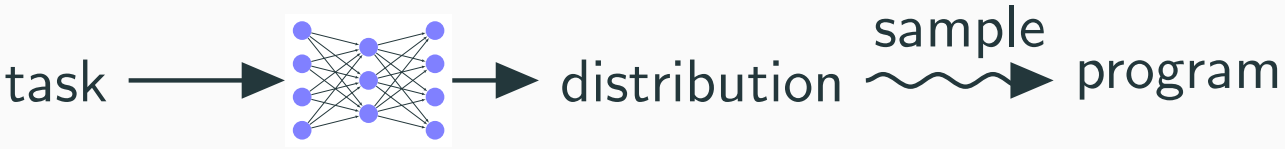

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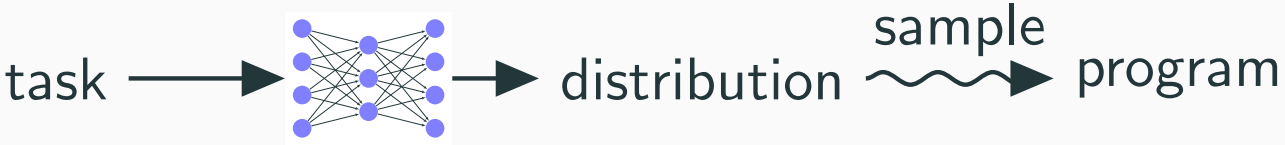
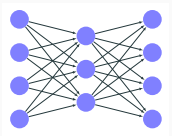


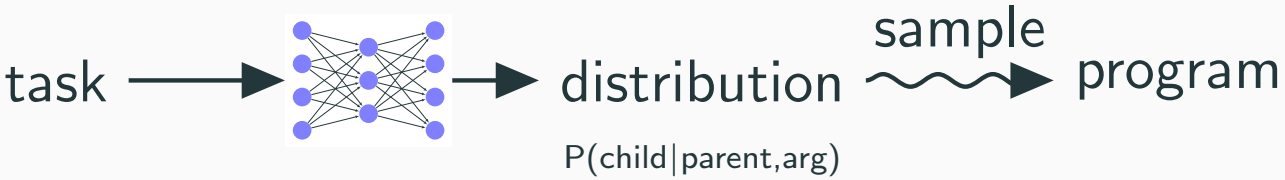


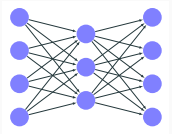
is a...

recurrent network (Devlin et al 2017)

unigram model (Menon et al 2013; Balog et al 2016)

Neural recognition model guides search





is a **"bigram" model over syntax trees**

Neural recognition model guides search

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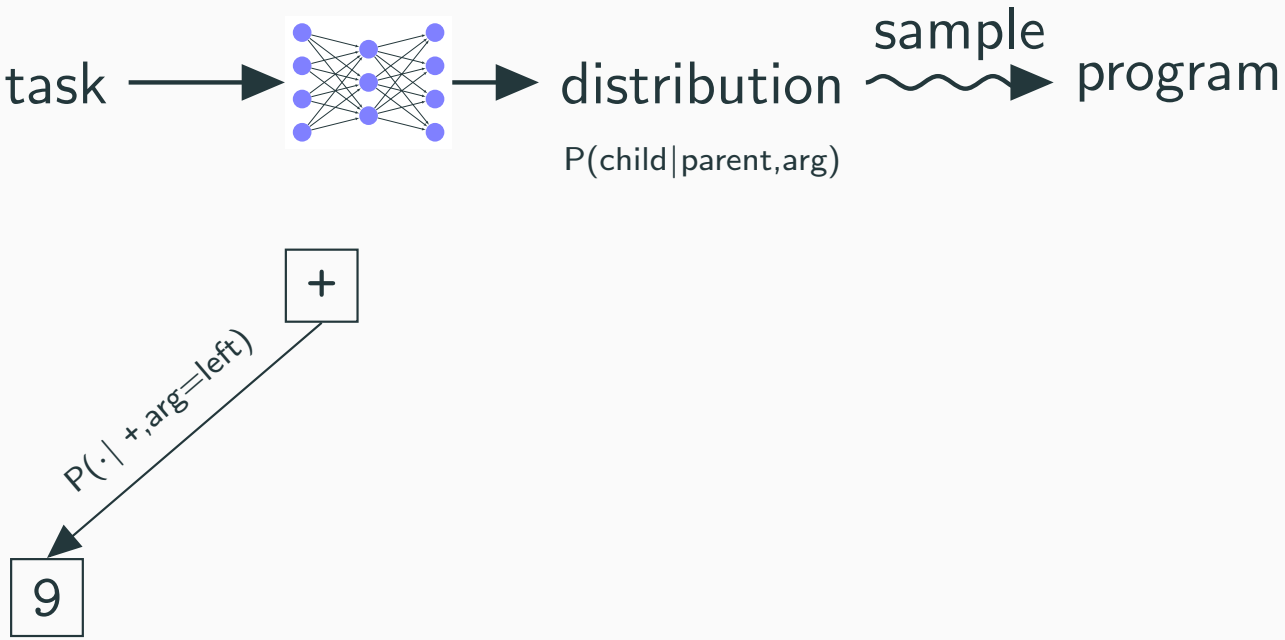

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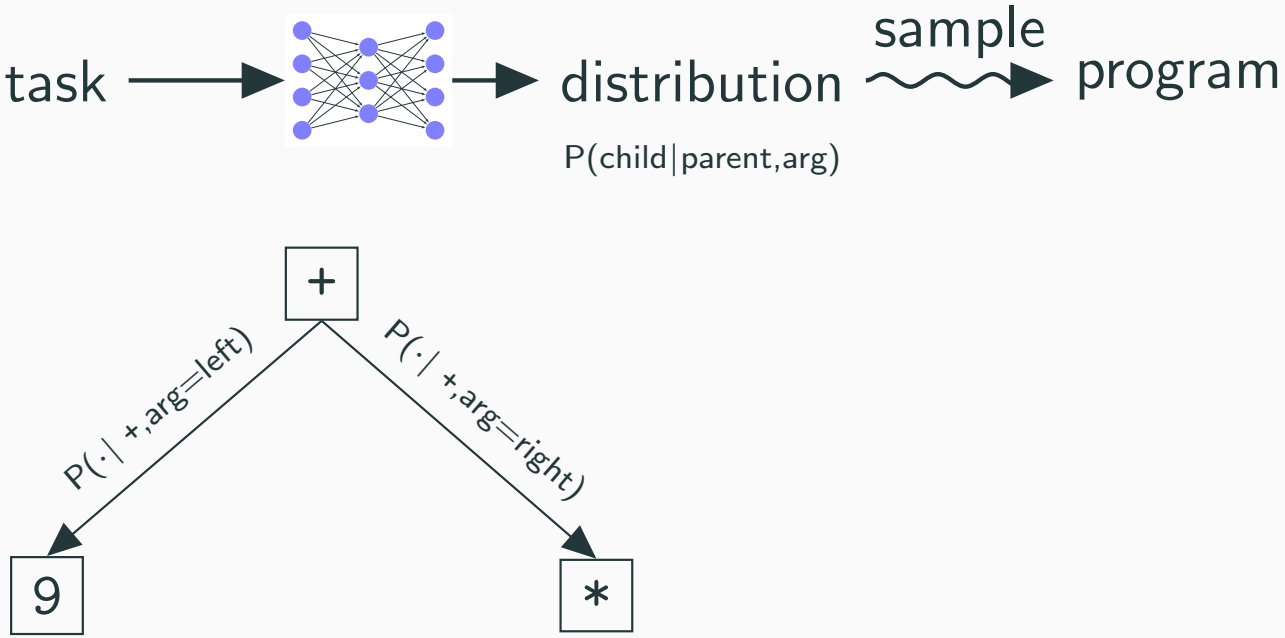

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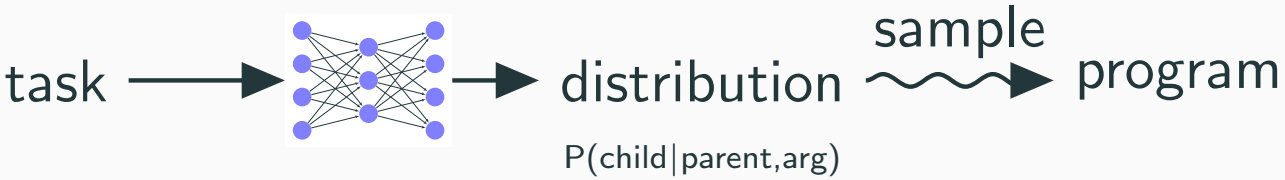

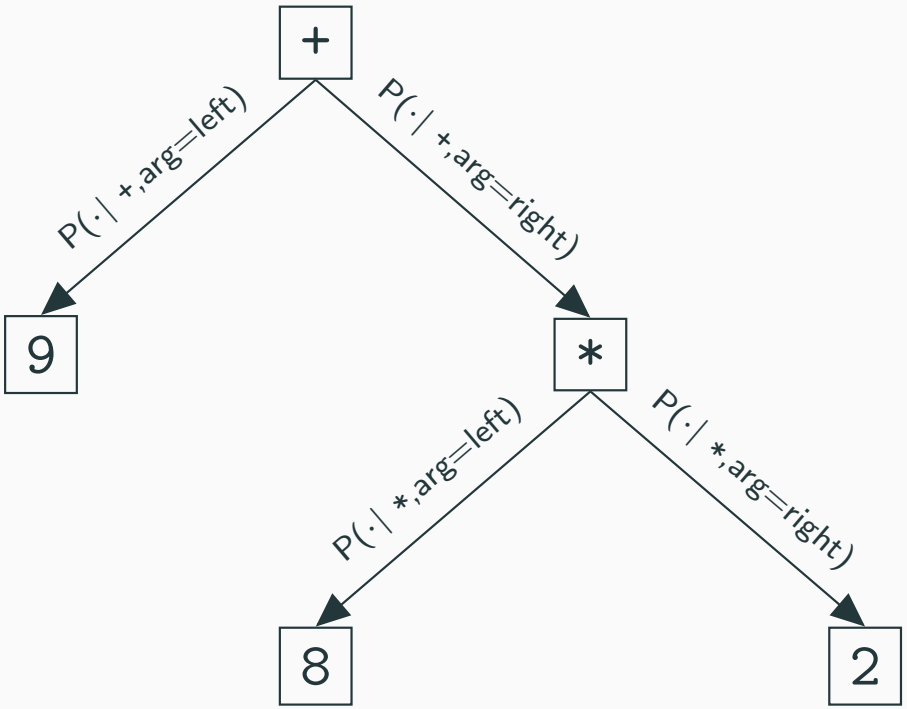

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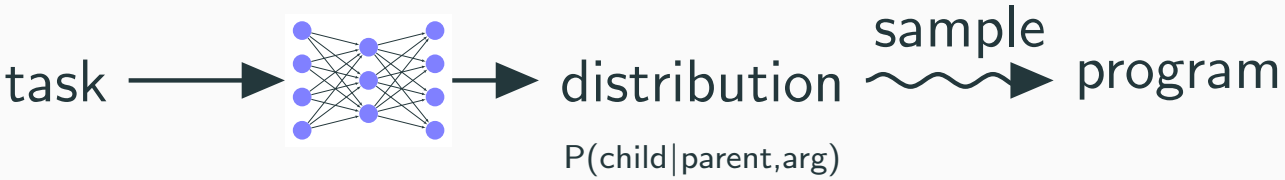
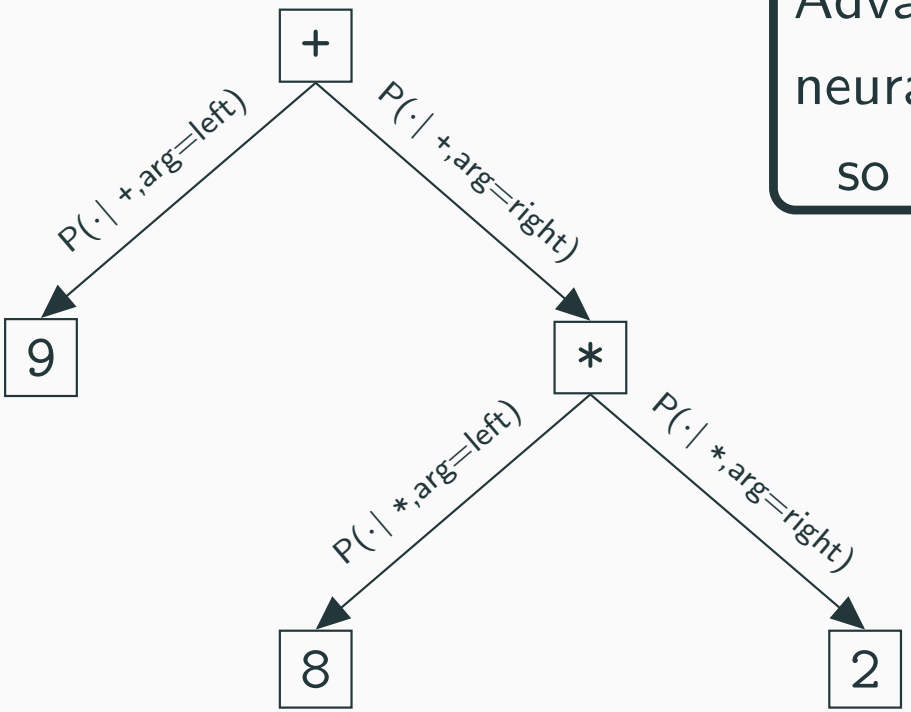


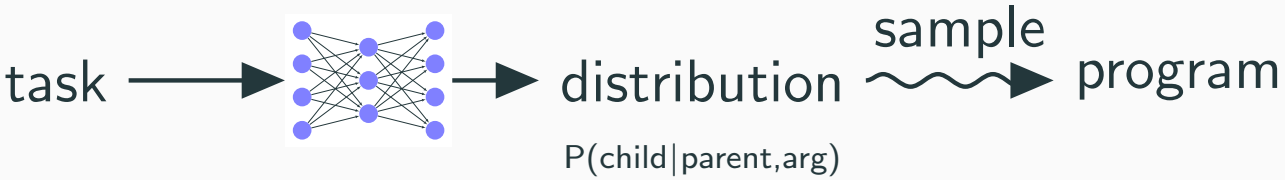


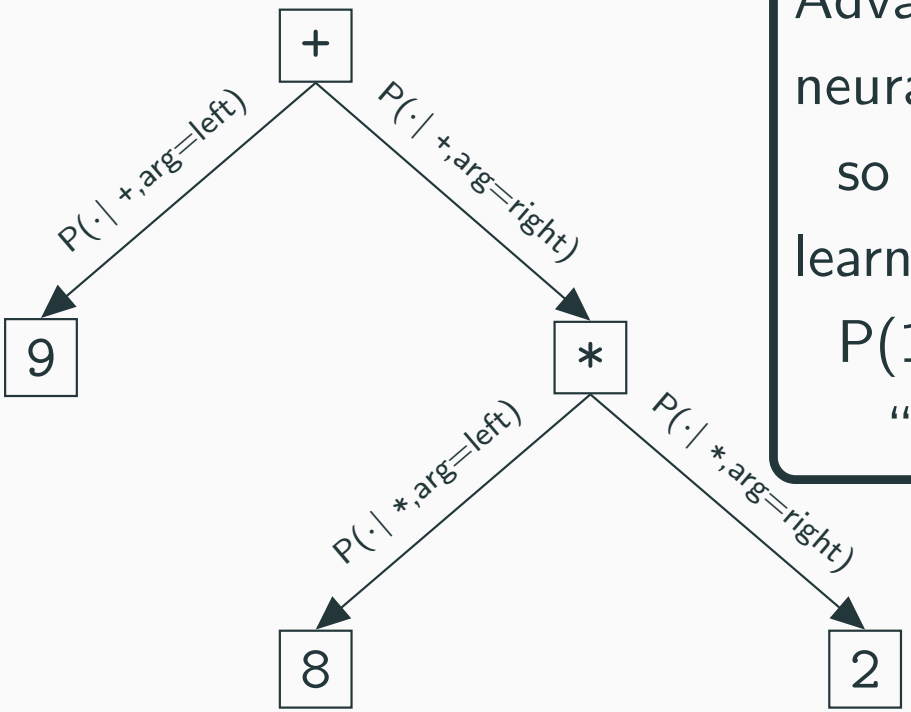
Advantages:

neural net runs once per task,

so CPU bottlenecks instead of GPU

Neural recognition model guides search





Advantages:

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learns to break syntactic symmetries:
$P(1|*,\text{arg}=\text{left})=0.0$
"do not multiply by one"

Program Induction and learning to learn

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DreamCoder Domains

List Processing

Sum List

```
[1 2 3] → 6
[4 6 8 1] → 17
```

Double

```
[1 2 3] → [2 4 6]
[4 5 1] → [8 10 2]
```

Text Editing

Abbreviate

```
Allen Newell → A.N.
Herb Simon → H.S.
```

Drop Last Three

```
shrdlu → shr
shakey → sha
```

Regexes

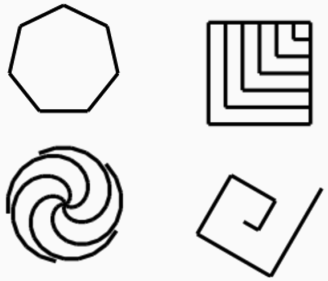
Phone numbers

```
(555) 867-5309
(650) 555-2368
```

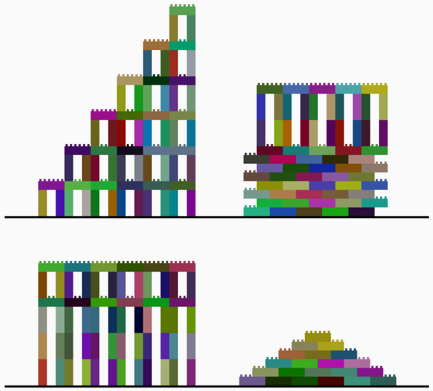
Currency

```
$100.25
$4.50
```

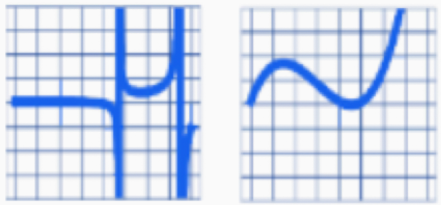
LOGO Graphics



Block Towers



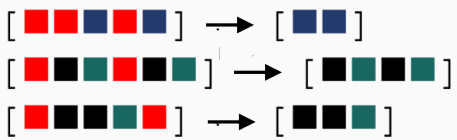
Symbolic Regression



$$y = f(x)$$

Recursive Programming

Filter Red



Physical Laws

$$\vec{a} = \frac{1}{m}\sum_i \vec{F}_i$$

$$\vec{F} \propto \frac{q_1 q_2}{|\vec{r}|^2}\hat{r}$$

Ellis, Wong, Nye, ..., Solar-Lezama, Tenenbaum. arxiv 2020.

DreamCoder Domains

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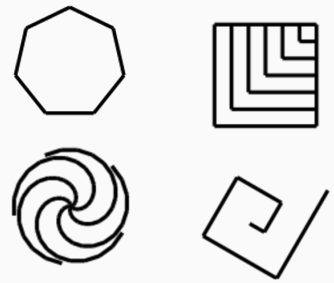
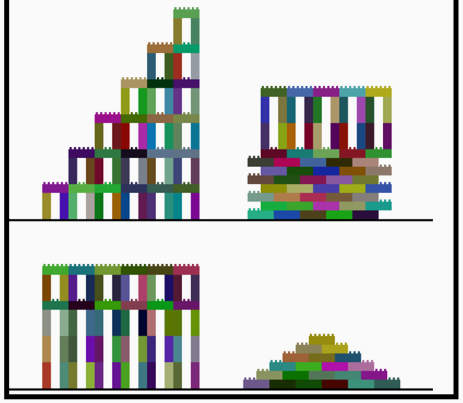
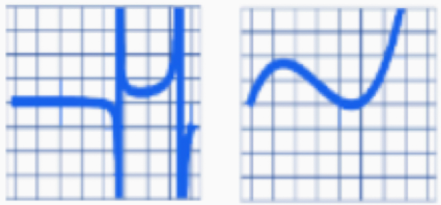
LOGO Graphics



Block Towers



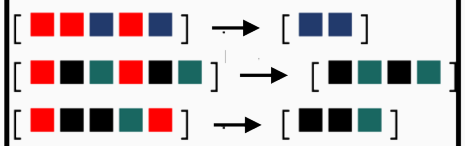
Symbolic Regression



$$y = f(x)$$

Recursive Programming

Filter Red



Physical Laws

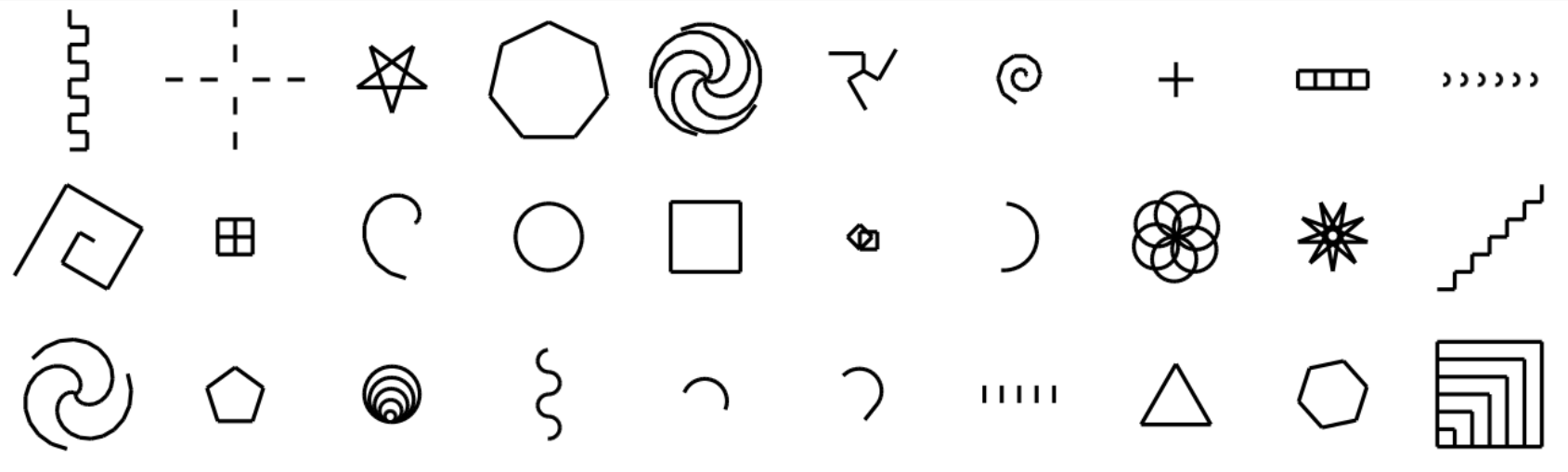
$$\vec{a} = \frac{1}{m}\sum_i \vec{F}_i$$

$$\vec{F} \propto \frac{q_1 q_2}{|\vec{r}|^2}\hat{r}$$

Ellis, Wong, Nye, ..., Solar-Lezama, Tenenbaum. arxiv 2020.

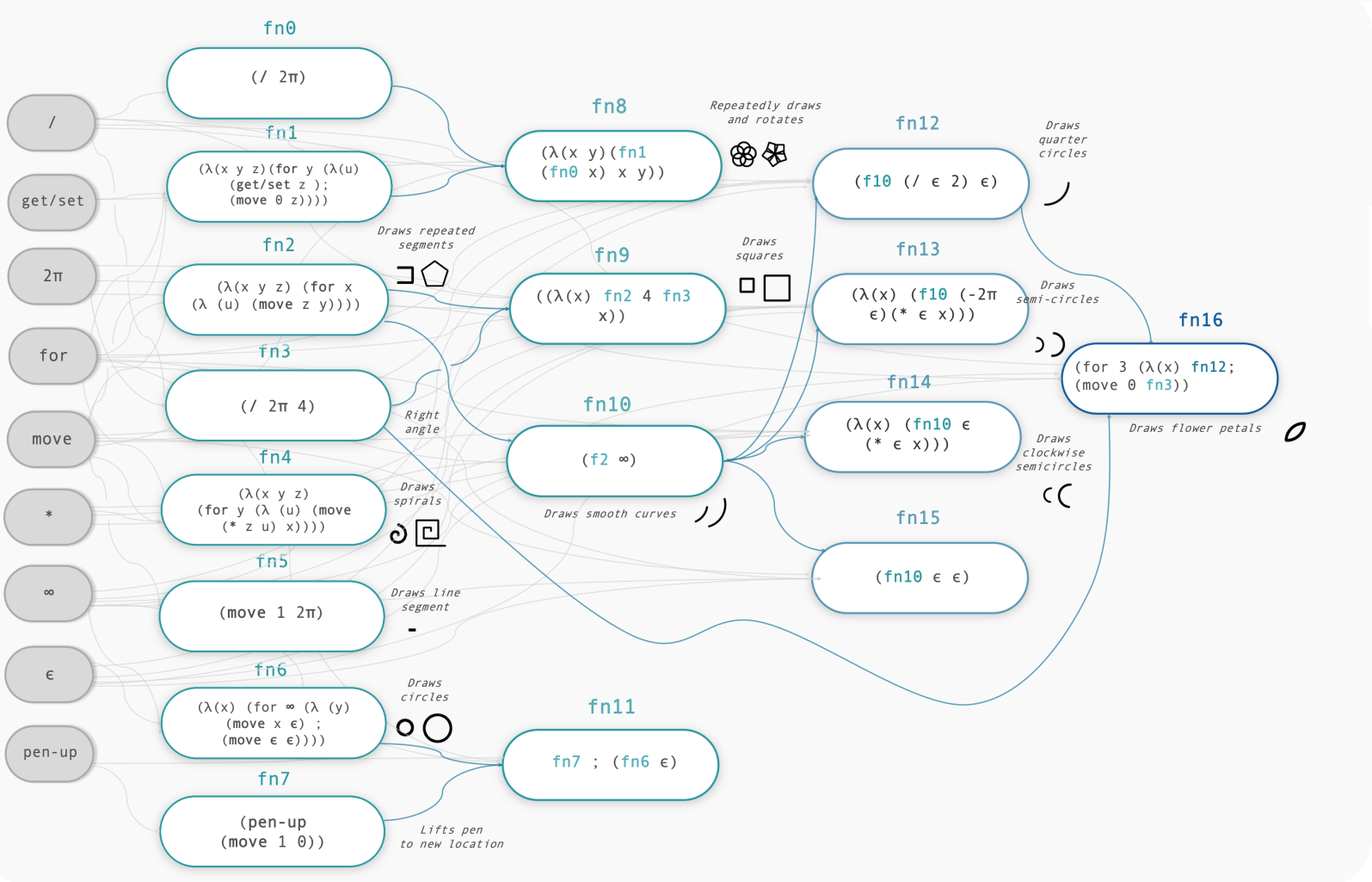
LOGO Turtle Graphics

30 out of 160 tasks



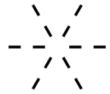
Ellis, Wong, Nye, ..., Solar-Lezama, Tenenbaum. arxiv 2020.

LOGO Turtle Graphics – learning an interpretable library



(fn8 5 (fn4 (* ϵ 2) ∞ ϵ))

(for 7 (λ (x) (fn9 x)))

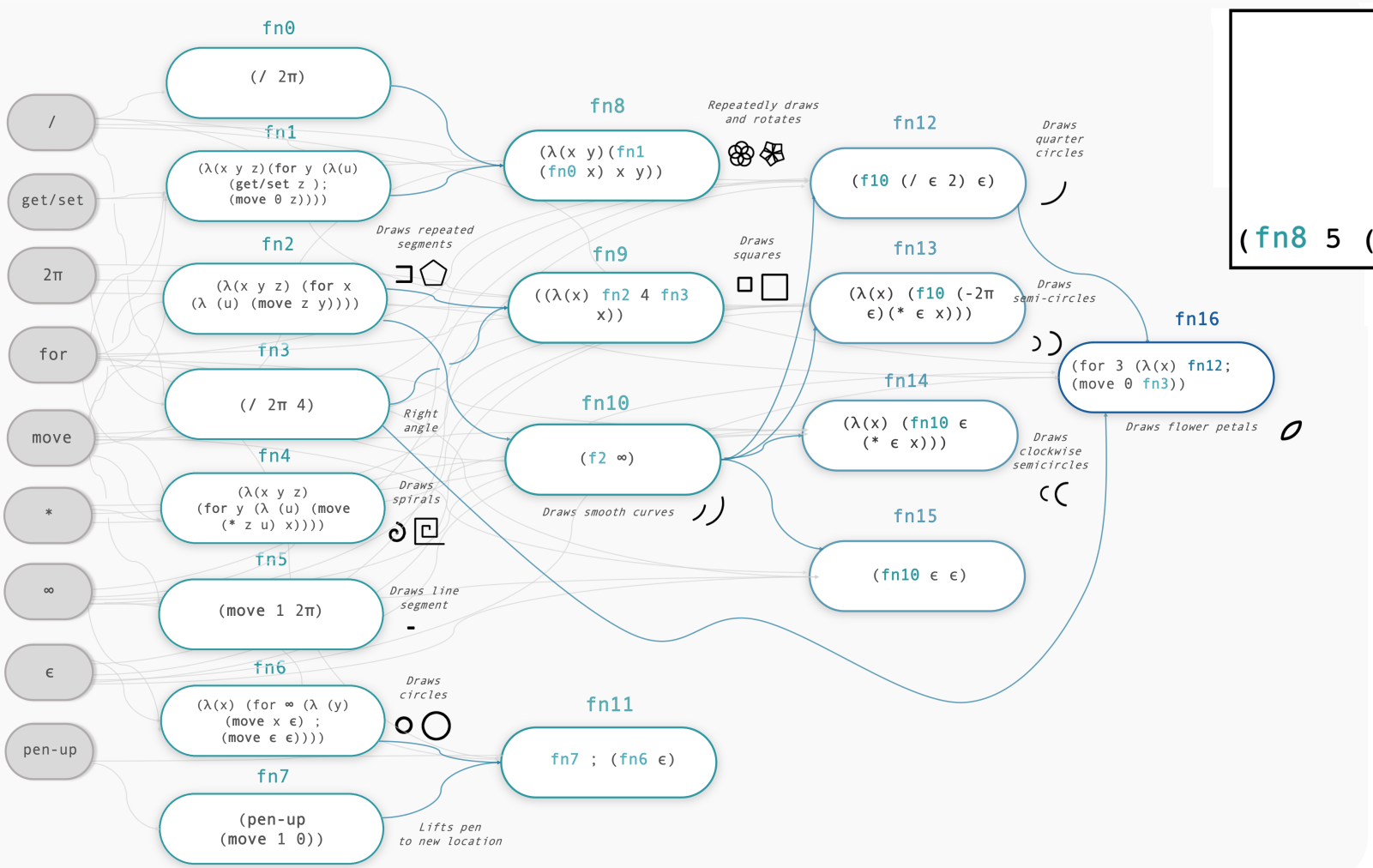


(fn8 6 (fn7 ; fn5 ; fn7 ; fn5))

(move 0 (fn0 7)); fn5 ; (fn13 4)

Ellis, Wong, Nye, ..., Solar-Lezama, Tenenbaum. arxiv 2020.

LOGO Turtle Graphics – learning an interpretable library



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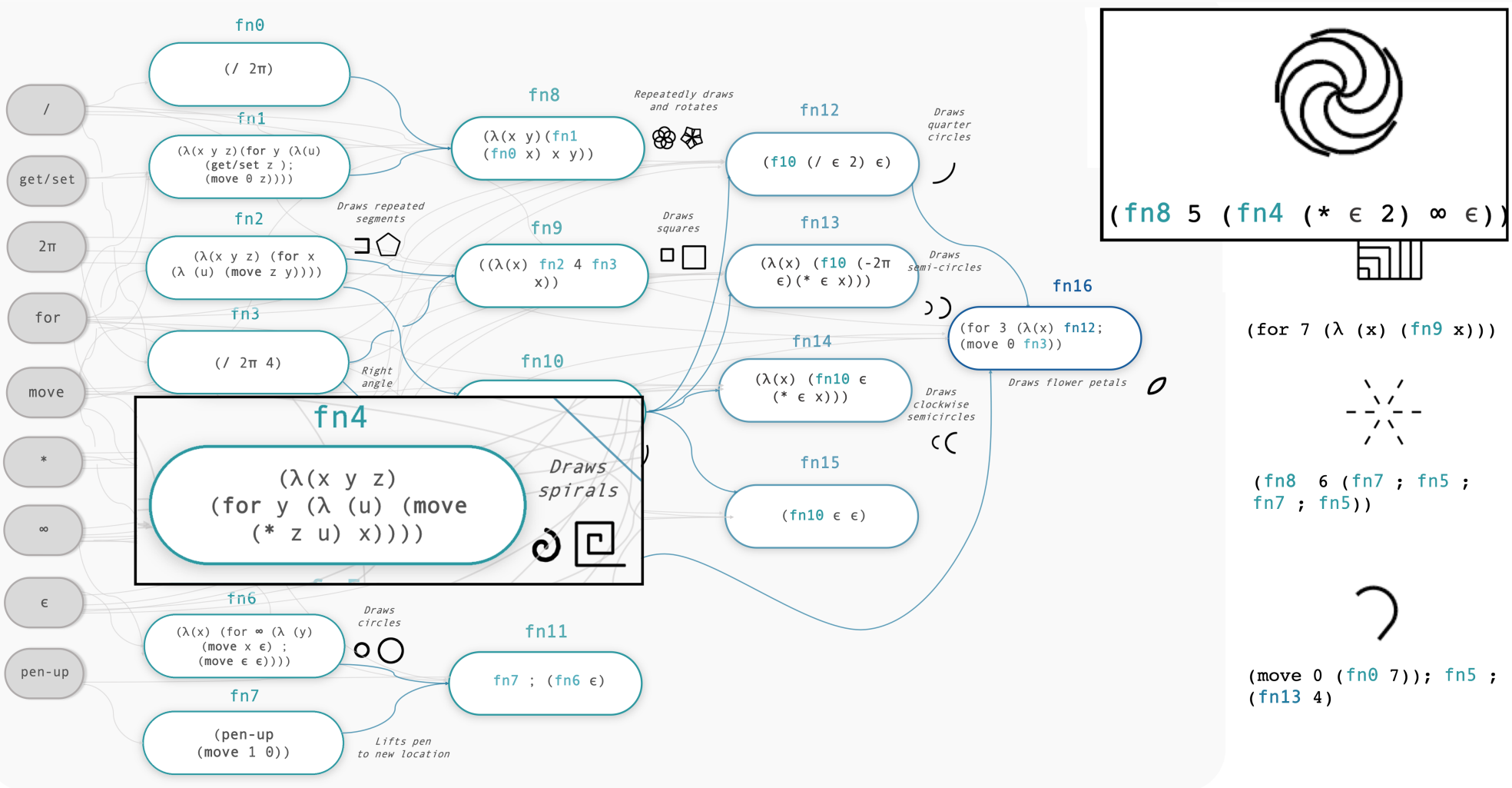

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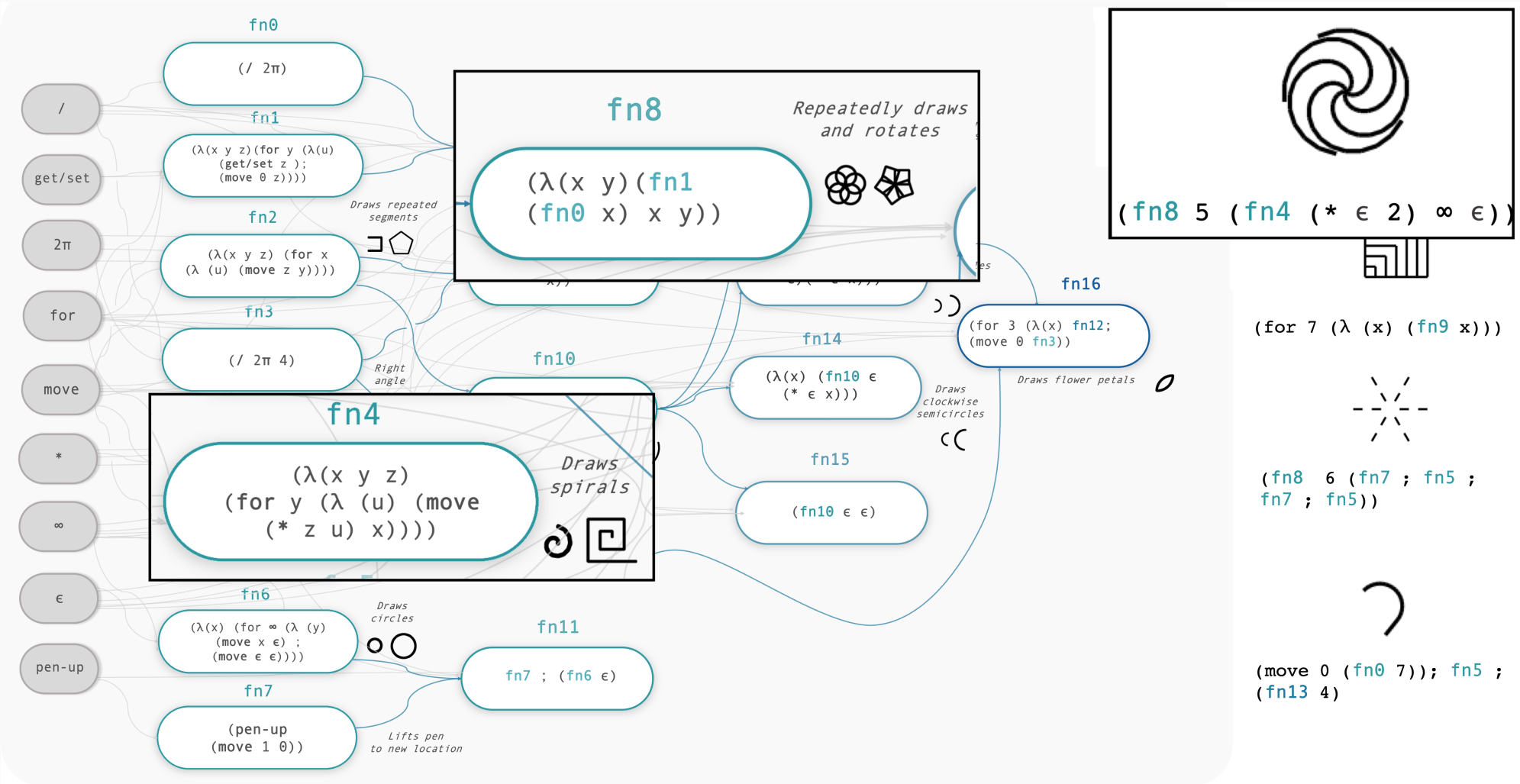
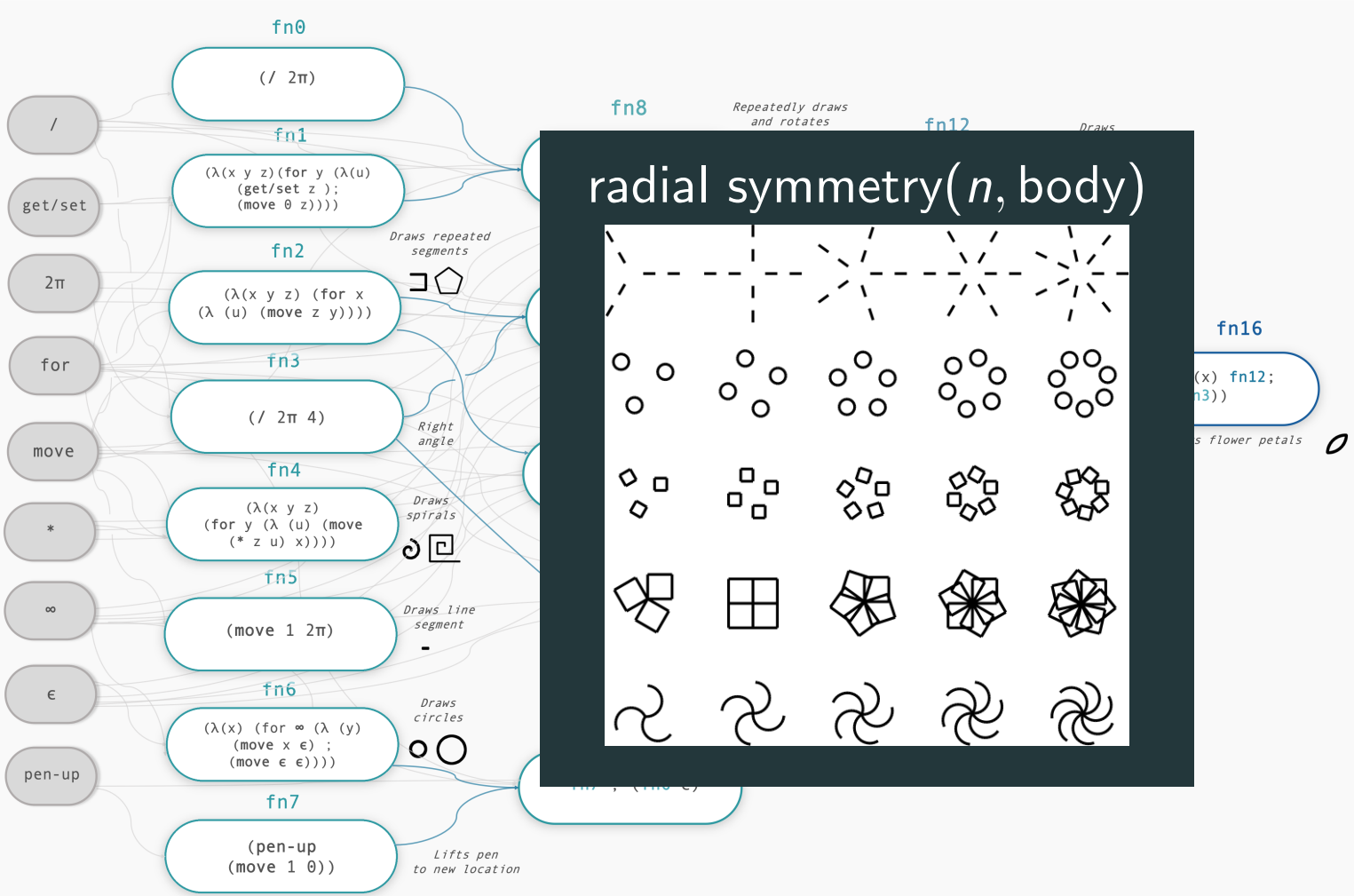
LOGO Turtle Graphics – learning an interpretable library



Ellis, Wong, Nye, ..., Solar-Lezama, Tenenbaum. arxiv 2020.

LOGO Turtle Graphics – learning an interpretable library



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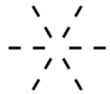

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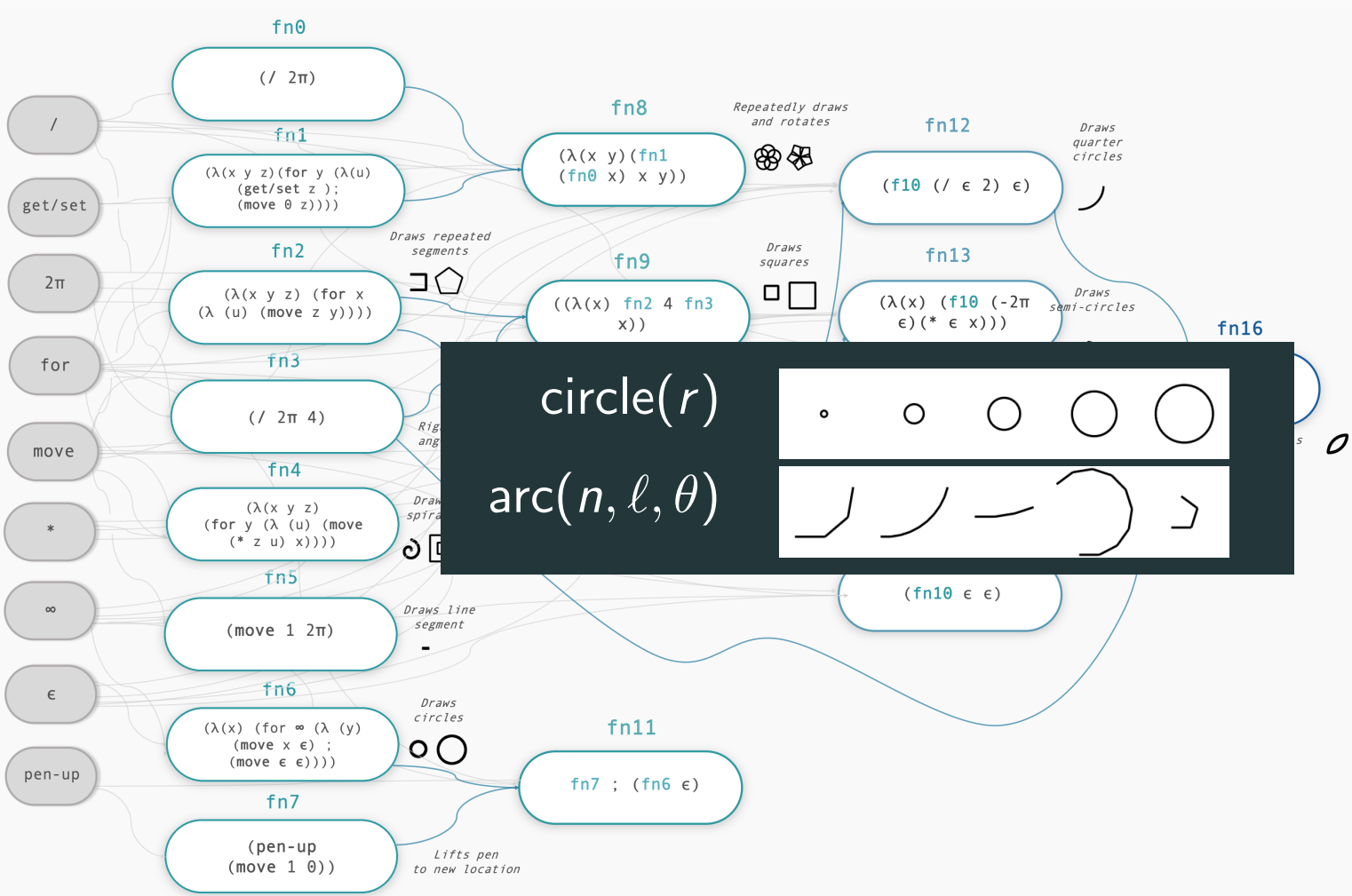
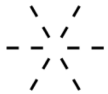


```
(fn8 5 (fn4 (* ϵ 2) ∞ ϵ))
```

```
(for 7 (λ (x) (fn9 x)))
```

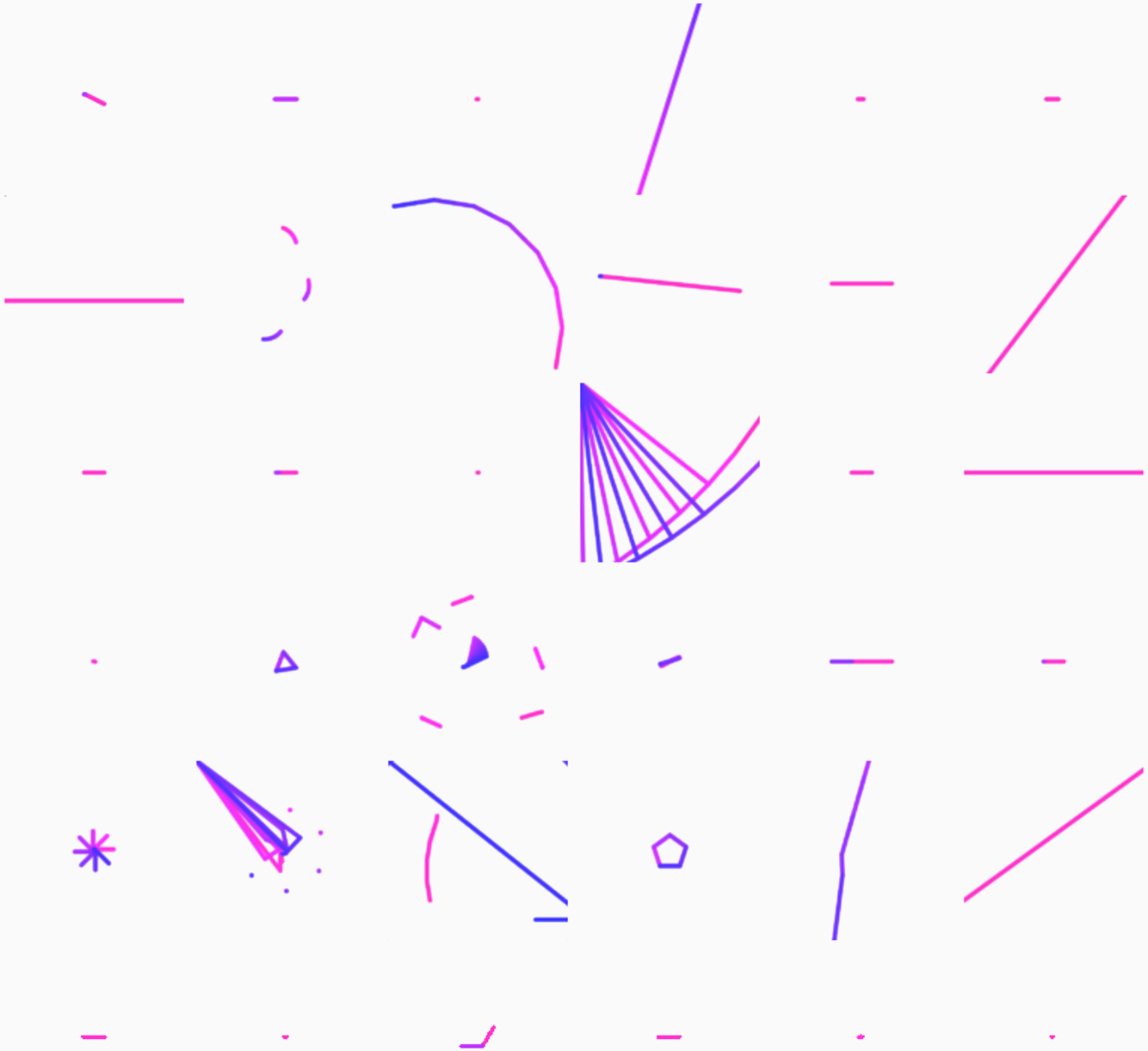


```
(fn8  6 (fn7 ; fn5 ;
fn7 ; fn5))
```

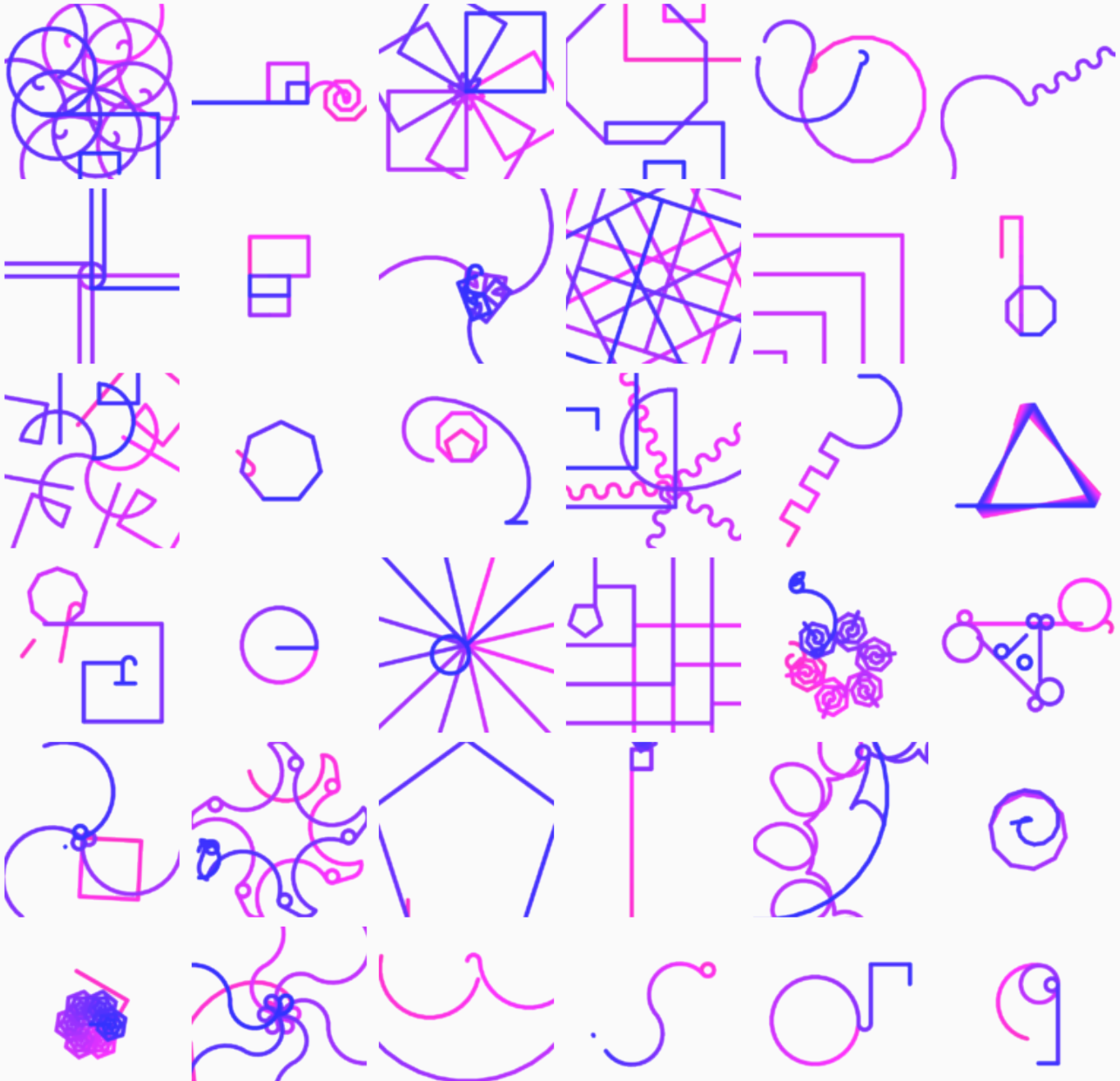
```
(move 0 (fn0 7)); fn5 ;
(fn13 4)
```

Ellis, Wong, Nye, ..., Solar-Lezama, Tenenbaum. arxiv 2020.

What does DreamCoder dream of? (before learning)

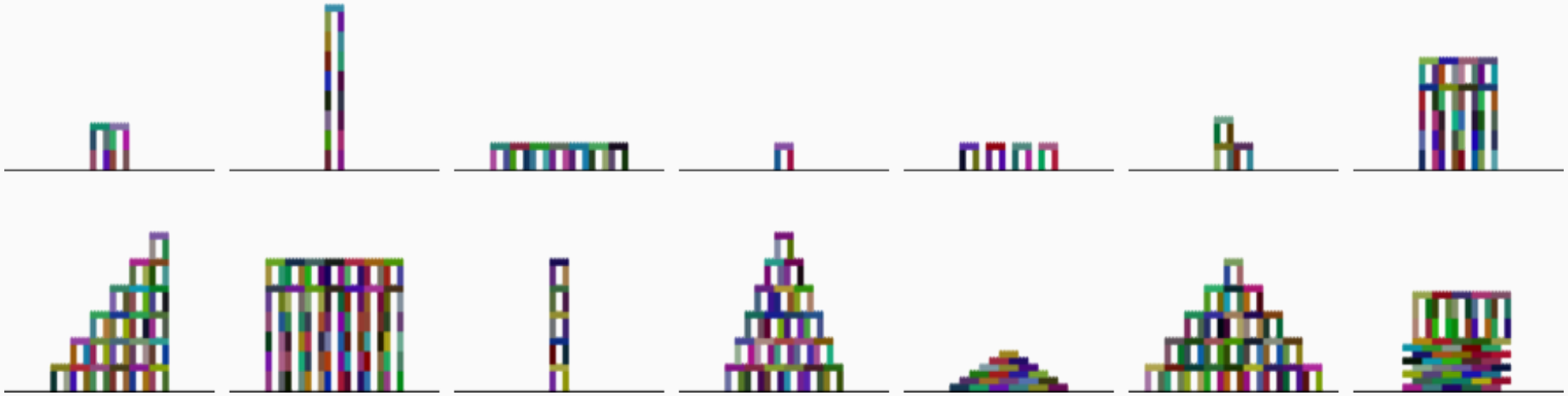


What does DreamCoder dream of? (after learning)



Planning to build towers

example tasks (112 total)



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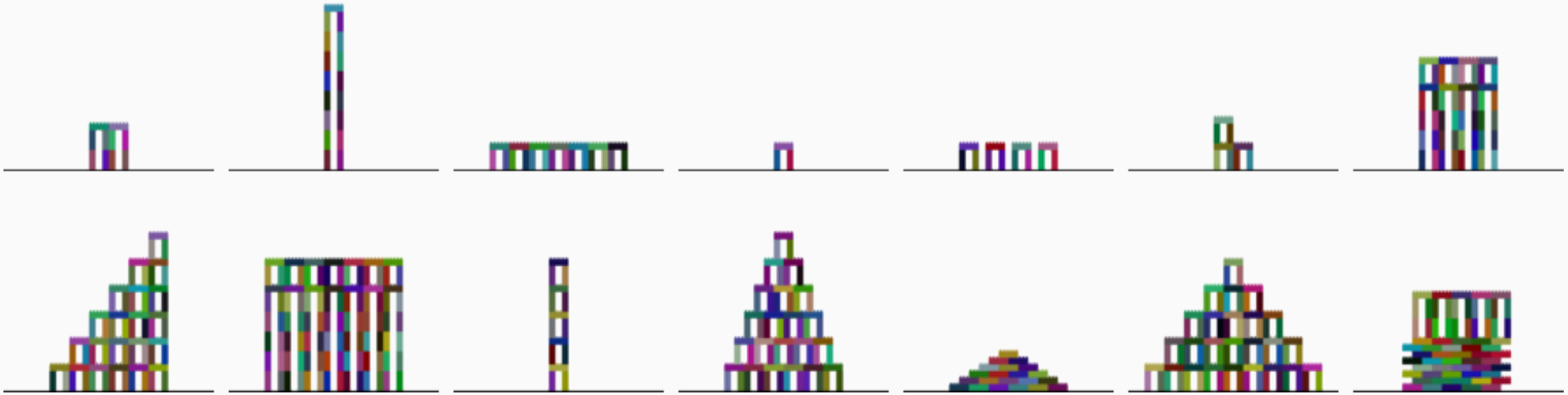
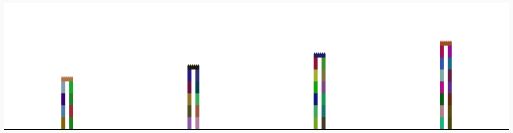
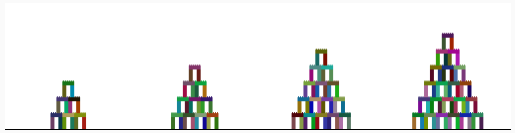


learned library routines ($\approx$ 20 total)

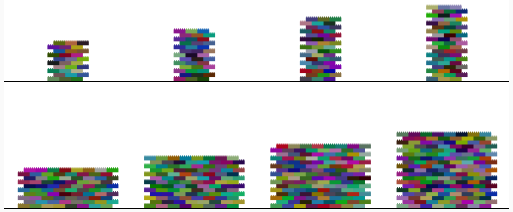
arch(h)



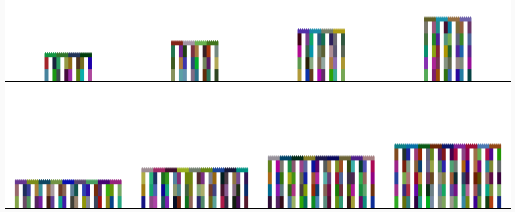
pyramid(h)



wall(w, h)

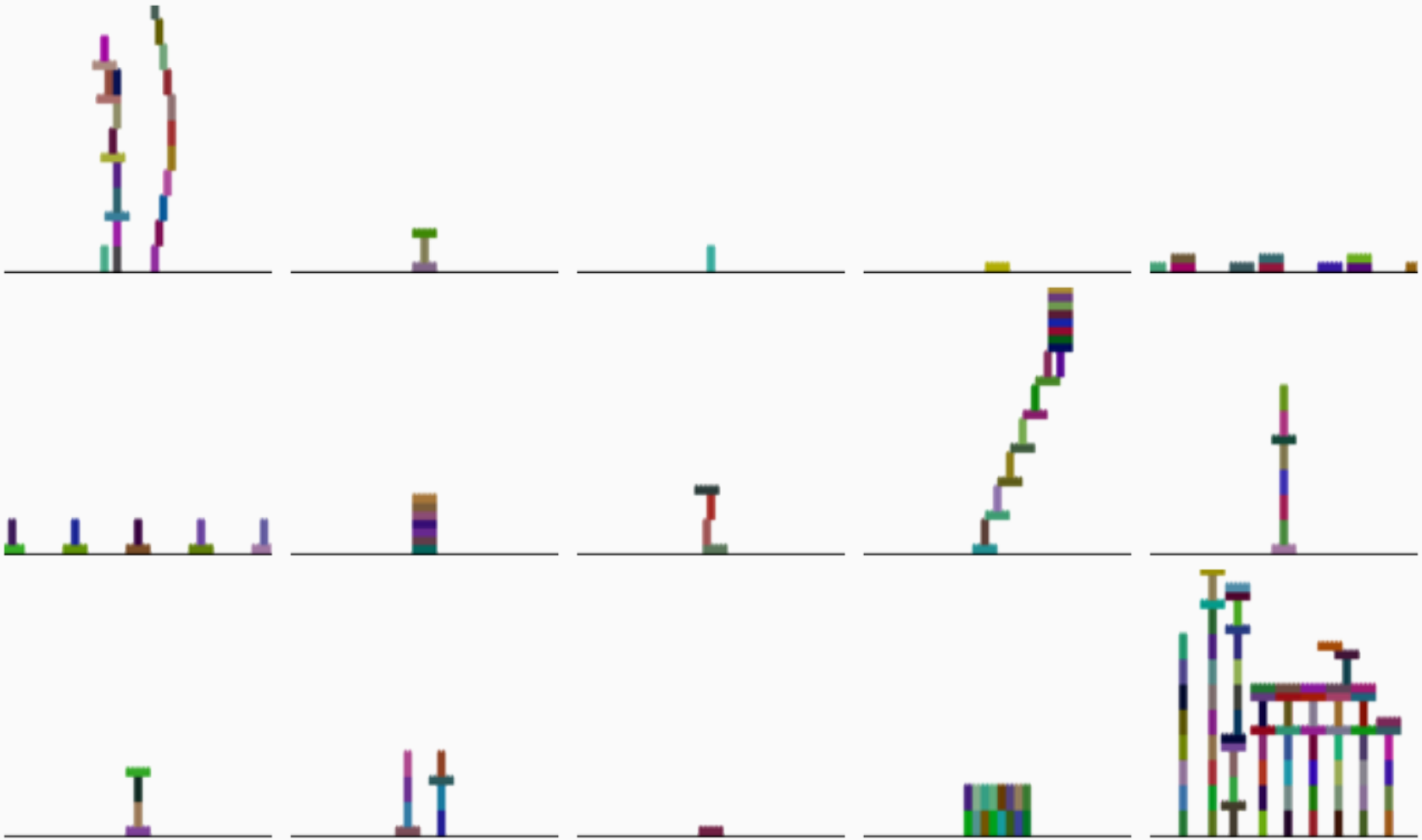


bridge(w, h)

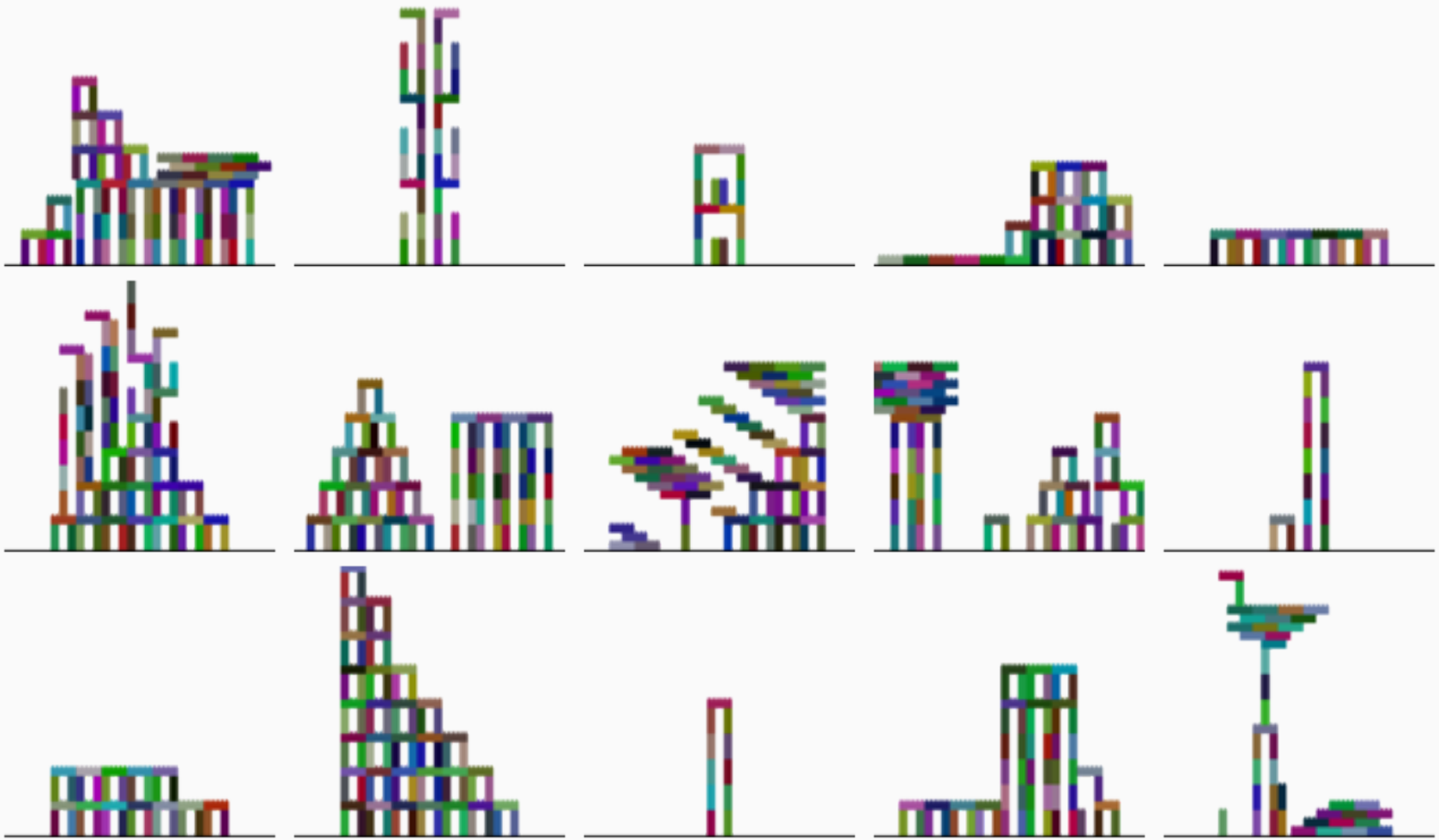


Ellis, Wong, Nye, ..., Solar-Lezama, Tenenbaum. arxiv 2020.

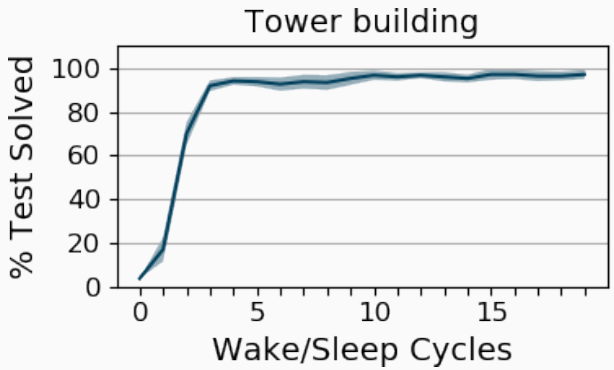
Dreams before learning



Dreams after learning

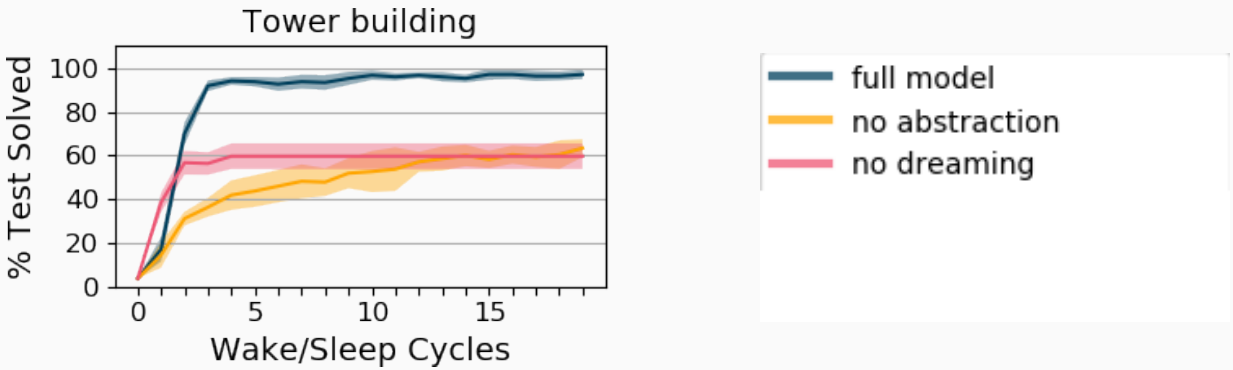


Learning dynamics



Ellis, Wong, Nye, ..., Solar-Lezama, Tenenbaum. arxiv 2020.

Learning dynamics



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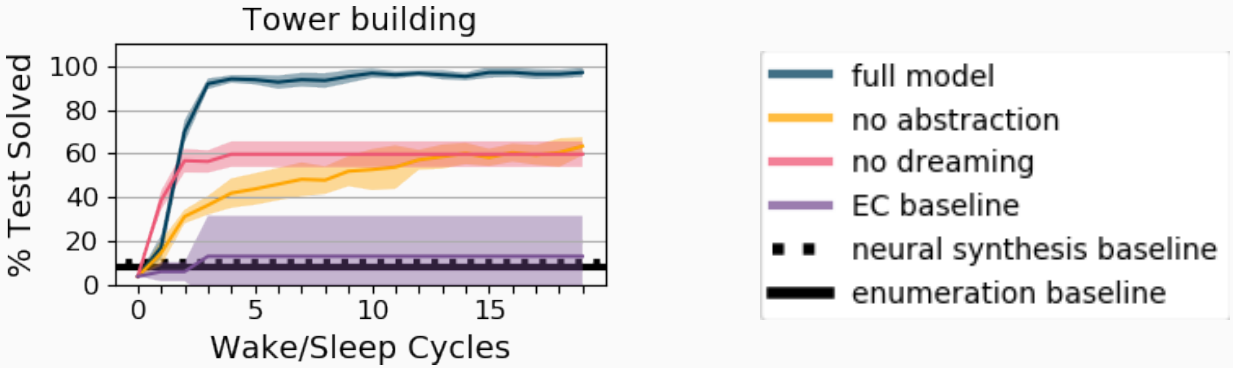
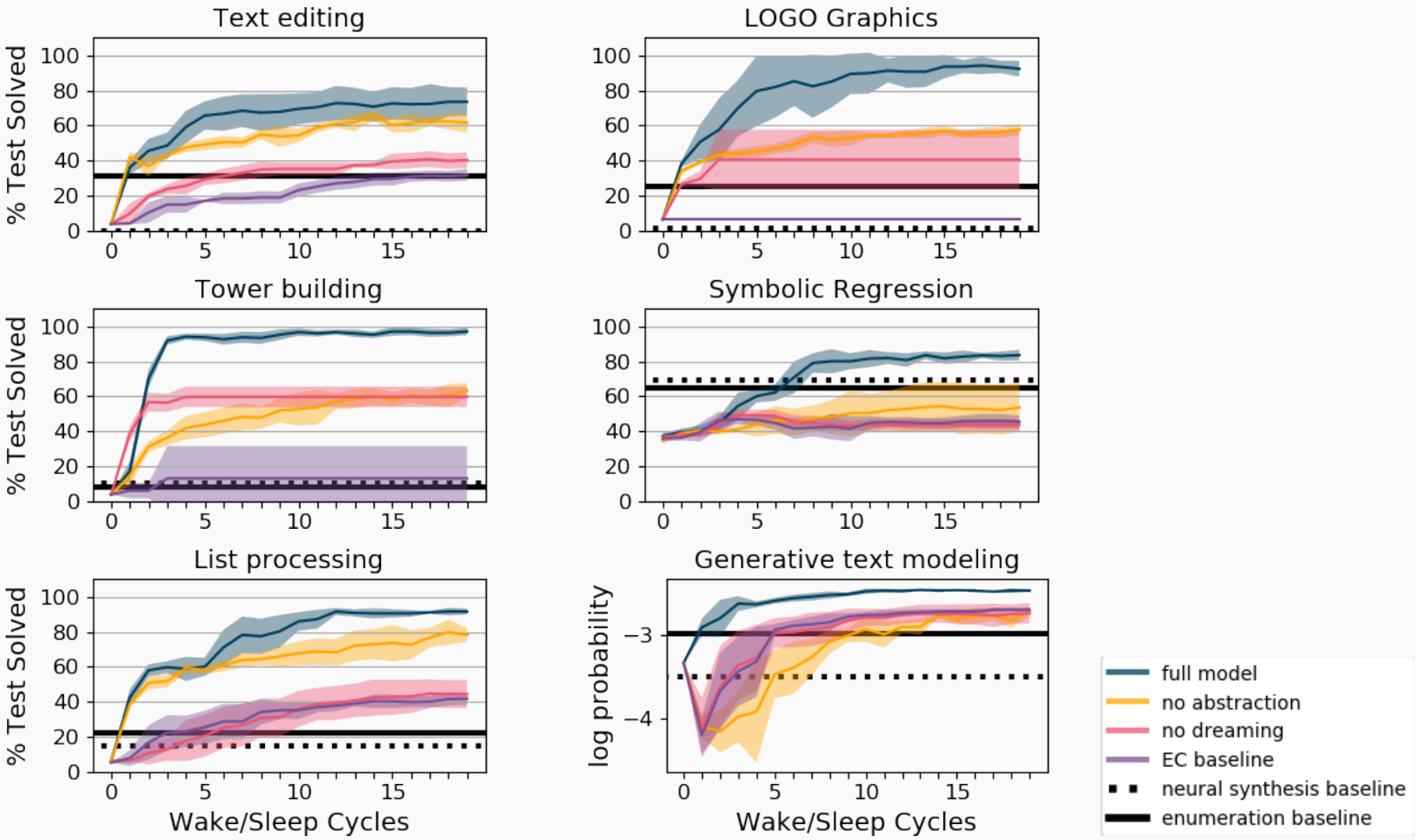
Learning dynamics



baselines: Exploration-Compression, EC [Dechter et al. 2013]
neural program synthesis, RobustFill [Devlin et al. 2017]
24 hours of brute-force enumeration

Ellis, Wong, Nye, ..., Solar-Lezama, Tenenbaum. arxiv 2020.

Learning dynamics



Ellis, Wong, Nye, ..., Solar-Lezama, Tenenbaum. arxiv 2020.

Synergy between recognition model and library learning

Problem-solving

Library

Recognition model

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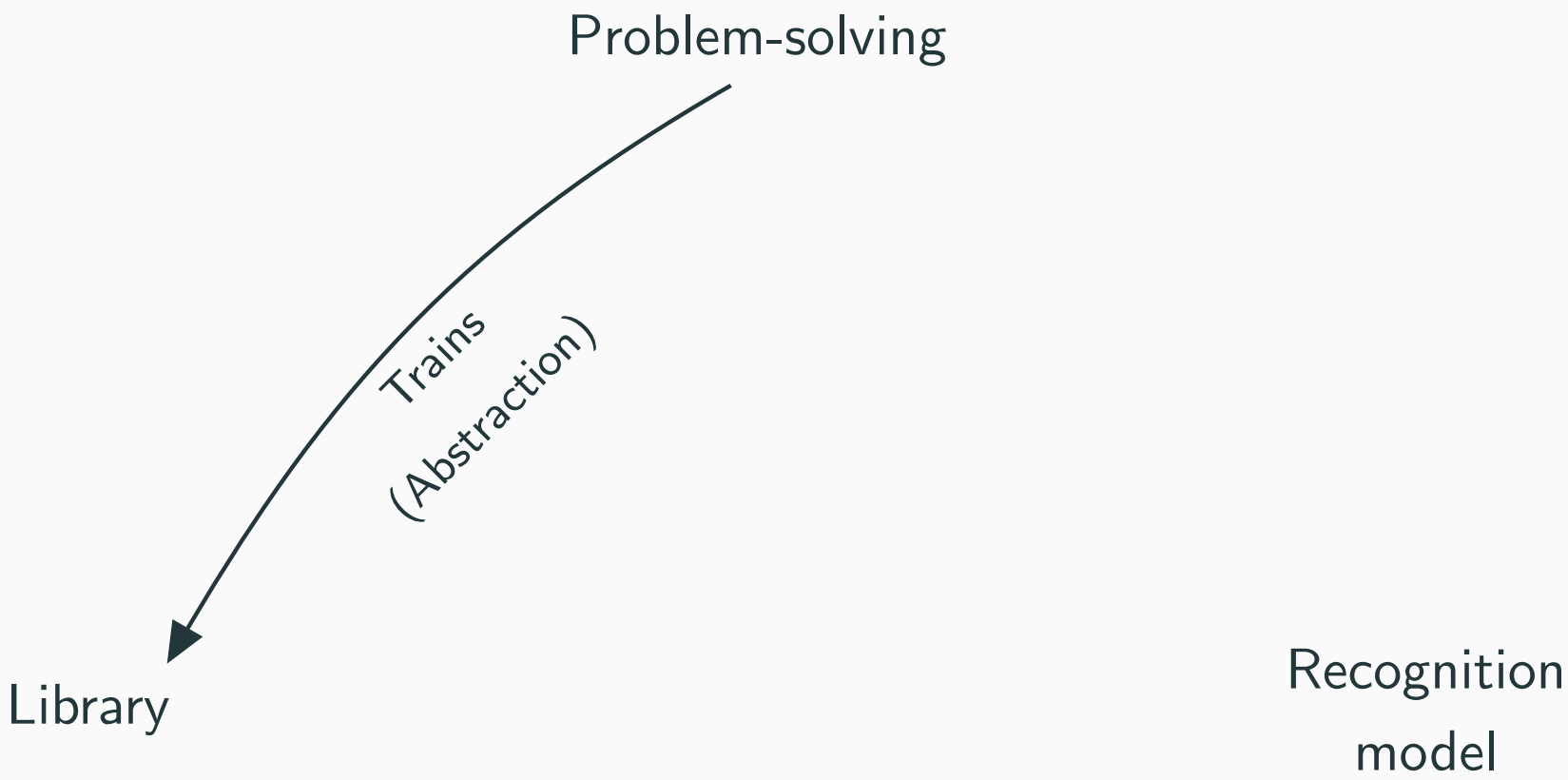
Synergy between recognition model and library learning



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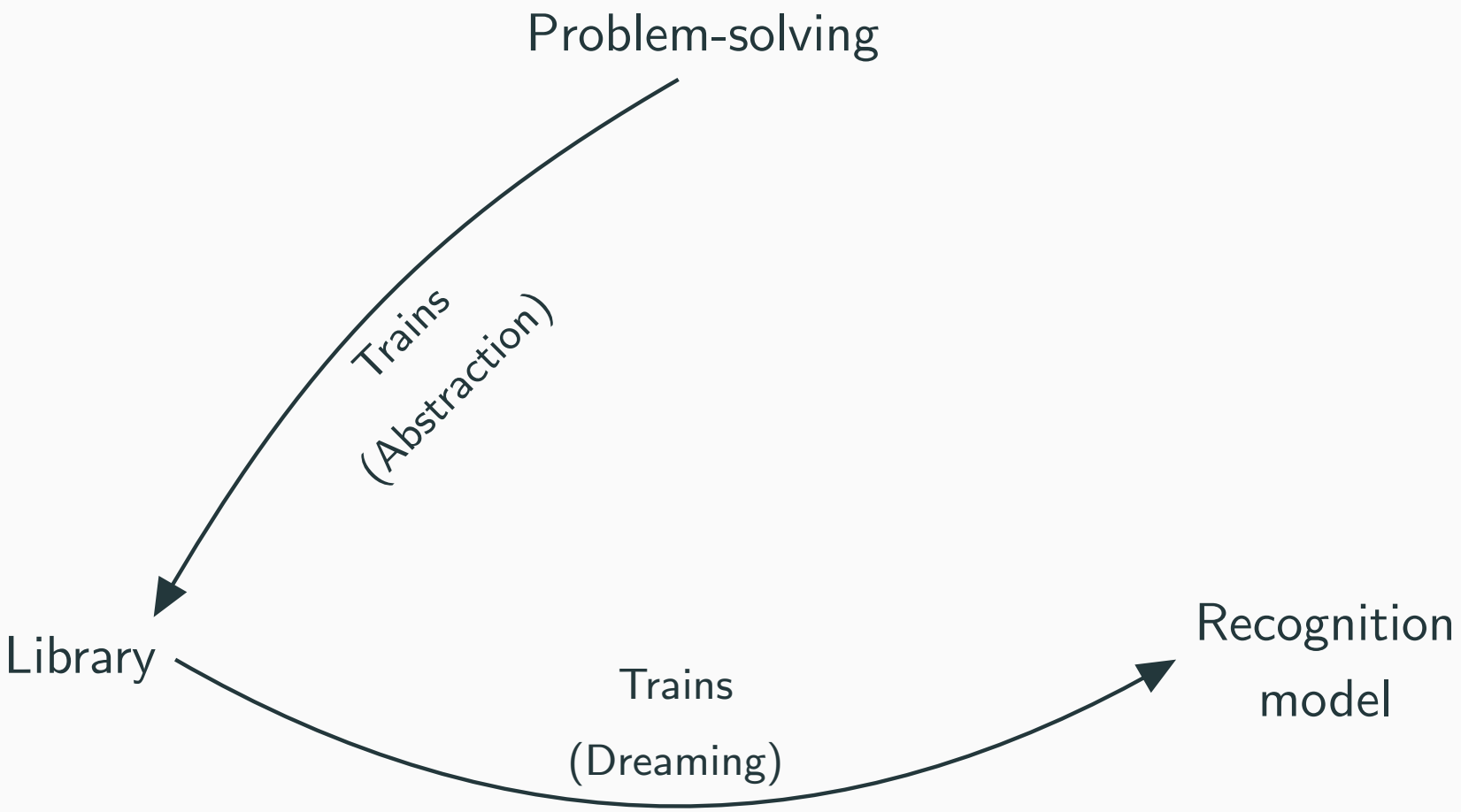

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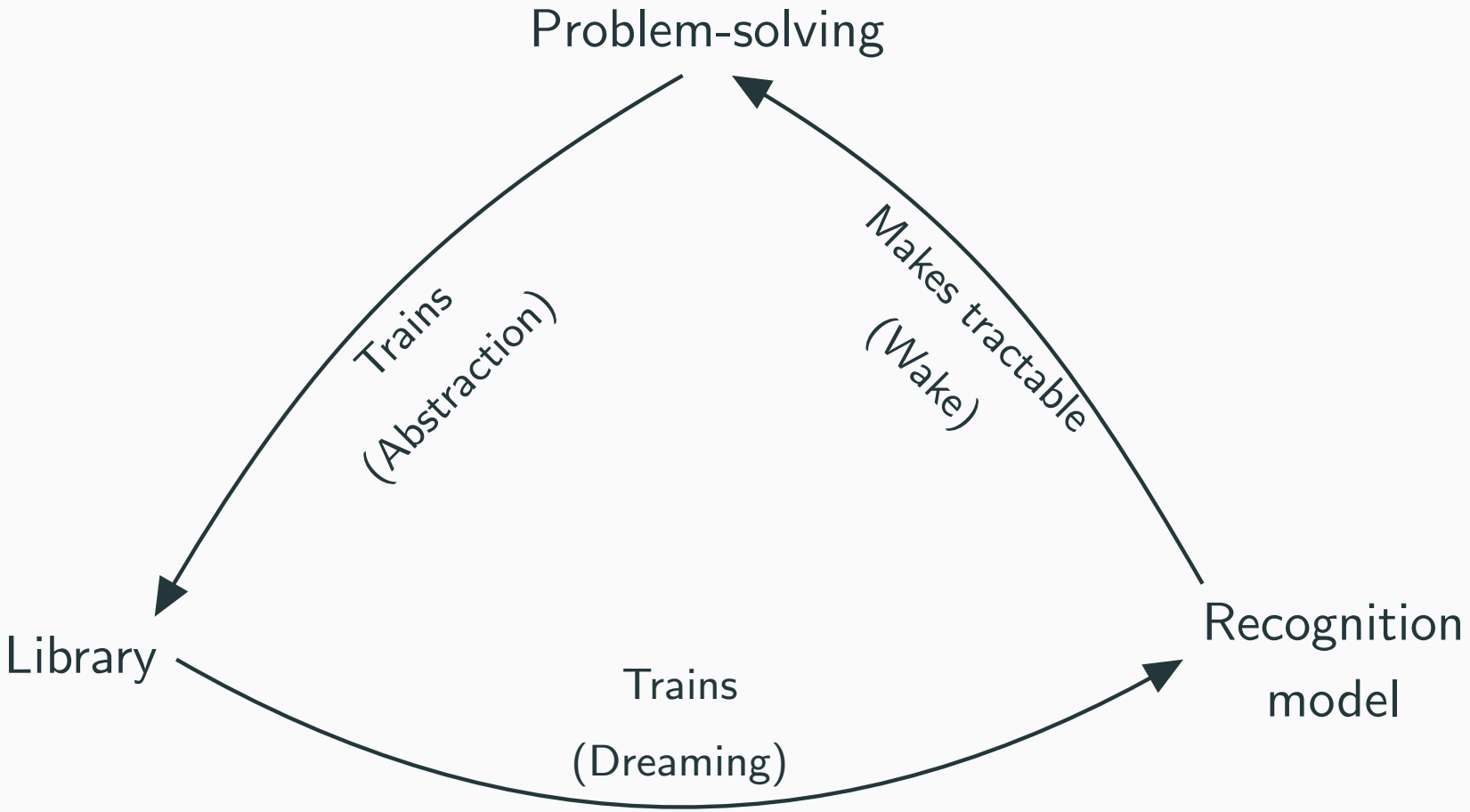

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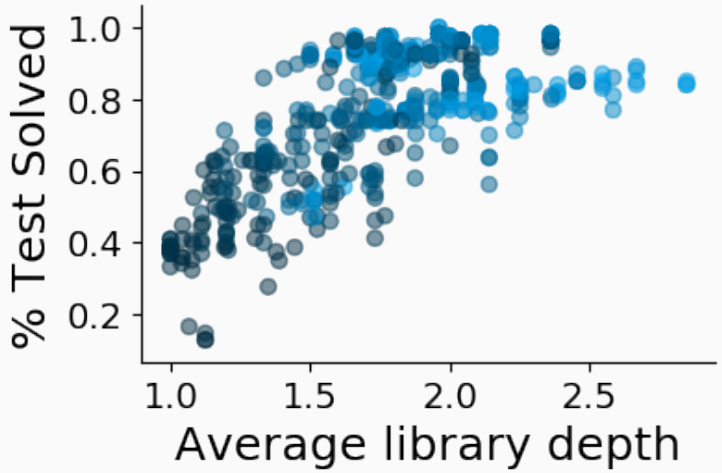
Evidence for dreaming bootstrapping better libraries



Darker: Early in learning

Brighter: Later in learning

Ellis, Wong, Nye, ..., Solar-Lezama, Tenenbaum. arxiv 2020.

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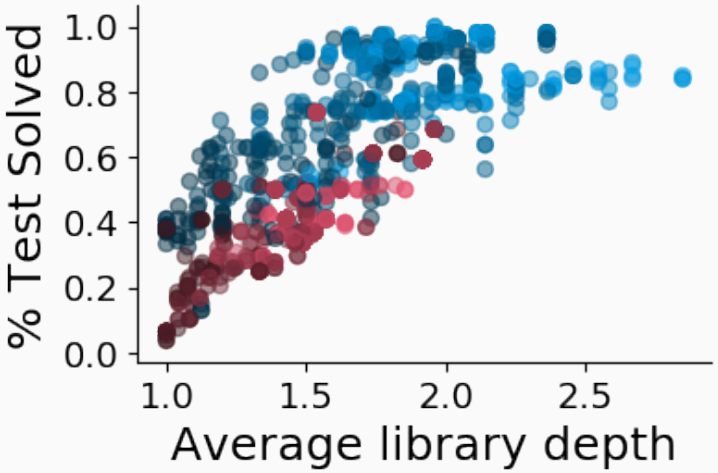

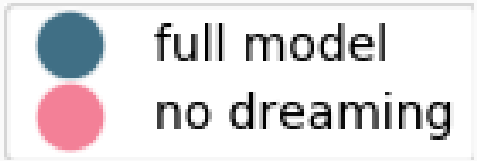

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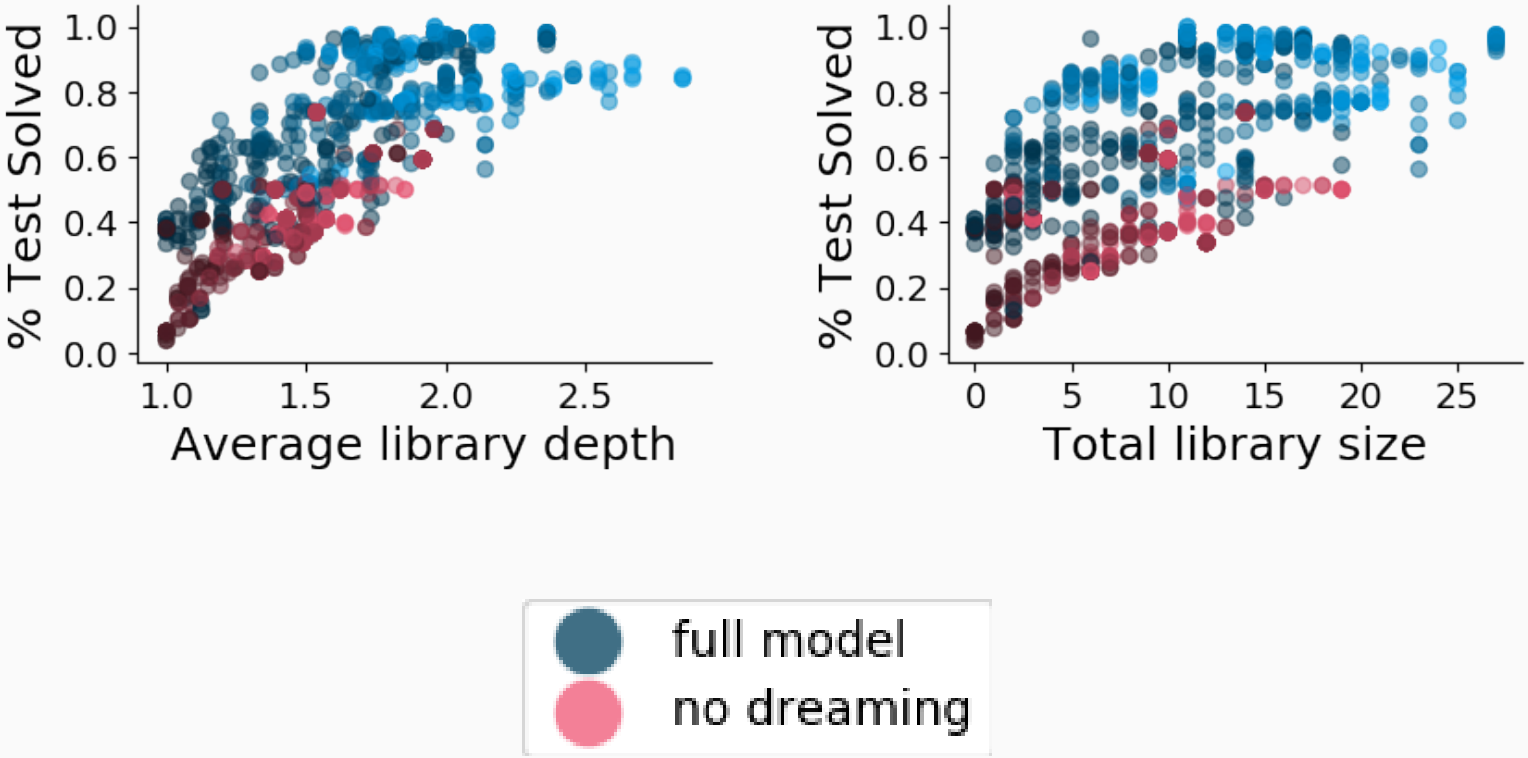

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From learning libraries, to learning languages

From learning libraries, to learning languages

modern functional programming $\rightarrow$ physics

From learning libraries, to learning languages

1950's Lisp $\rightarrow$ modern functional programming $\rightarrow$ physics

Physics Formula Sheet

Mechanics

$x = x_0 + v_{x0}t + \frac{1}{2}a_x t^2$

$v = v_0 + at$

$v_x^2 - v_{x0}^2 = 2a(x - x_0)$

$\vec{a} = \frac{\Sigma \vec{F}}{m} = \frac{\vec{F}_{net}}{m}$

$|\vec{F}_{friction}| \leq \mu |\vec{F}_{Normal}|$

$\vec{p} = m\vec{v}$

$\Delta \vec{p} = \vec{F}\Delta t$

$KE = \frac{1}{2}mv^2$

$\Delta PE = mg\Delta y$

$\Delta E = W = Fd\cos\theta$

$a_c = \frac{v^2}{r}$

$\theta = \theta_0 + \omega_0 t + \frac{1}{2}\alpha t^2$

$\omega = \omega_0 + \alpha t$

$T = \frac{2\pi}{\omega} = \frac{1}{f}$

$\nu = f\lambda$

$x = A\cos(2\pi f t)$

$\vec{\alpha} = \frac{\Sigma \vec{\tau}}{I} = \frac{\vec{\tau}_{net}}{I}$

$\vec{\tau} = r \times F$

$L = I\,\omega$

$\Delta L = \tau \Delta t$

$|\vec{F}_{spring}| = k|\vec{x}|$

$PE_{spring} = \frac{1}{2}kx^2$

$T_{spring} = 2\pi\sqrt{\frac{m}{k}}$

$T_{pendulum} = 2\pi\sqrt{\frac{\ell}{g}}$

$|\vec{F}_{gravity}| = G\frac{m_1 m_2}{r^2}$

$|\vec{F}_{gravity}| = m\vec{g}$

$PE_{gravity} = -G\frac{m_1 m_2}{r}$

$\rho = \frac{m}{V}$

$KE = \frac{1}{2}I\,\omega^2$

Electricity

$|\vec{F}_E| = k\left|\frac{q_1 q_2}{r^2}\right|$

$\Delta V = IR$

$R = \frac{\rho \ell}{A}$

$I = \frac{\Delta q}{\Delta t}$

$P = I\Delta V$

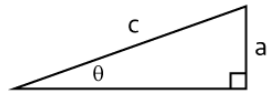
$R_{series} = R_1 + R_2 + \ldots + R_n$

$\frac{1}{R_{Parallel}} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots + \frac{1}{R_n}$

Geometry

Rectangle	$A = bh$	Rectangular Solid	$V = \ell wh$	Triangle	$A = \frac{1}{2}bh$
Circle	$A = \pi r^2$ $C = 2\pi r$	Cylinder	$V = \pi r^2 \ell$ $S = 2\pi r\ell + 2\pi r^2$	Sphere	$V = \frac{4}{3}\pi r^3$ $S = 4\pi r^2$

Trigonometry



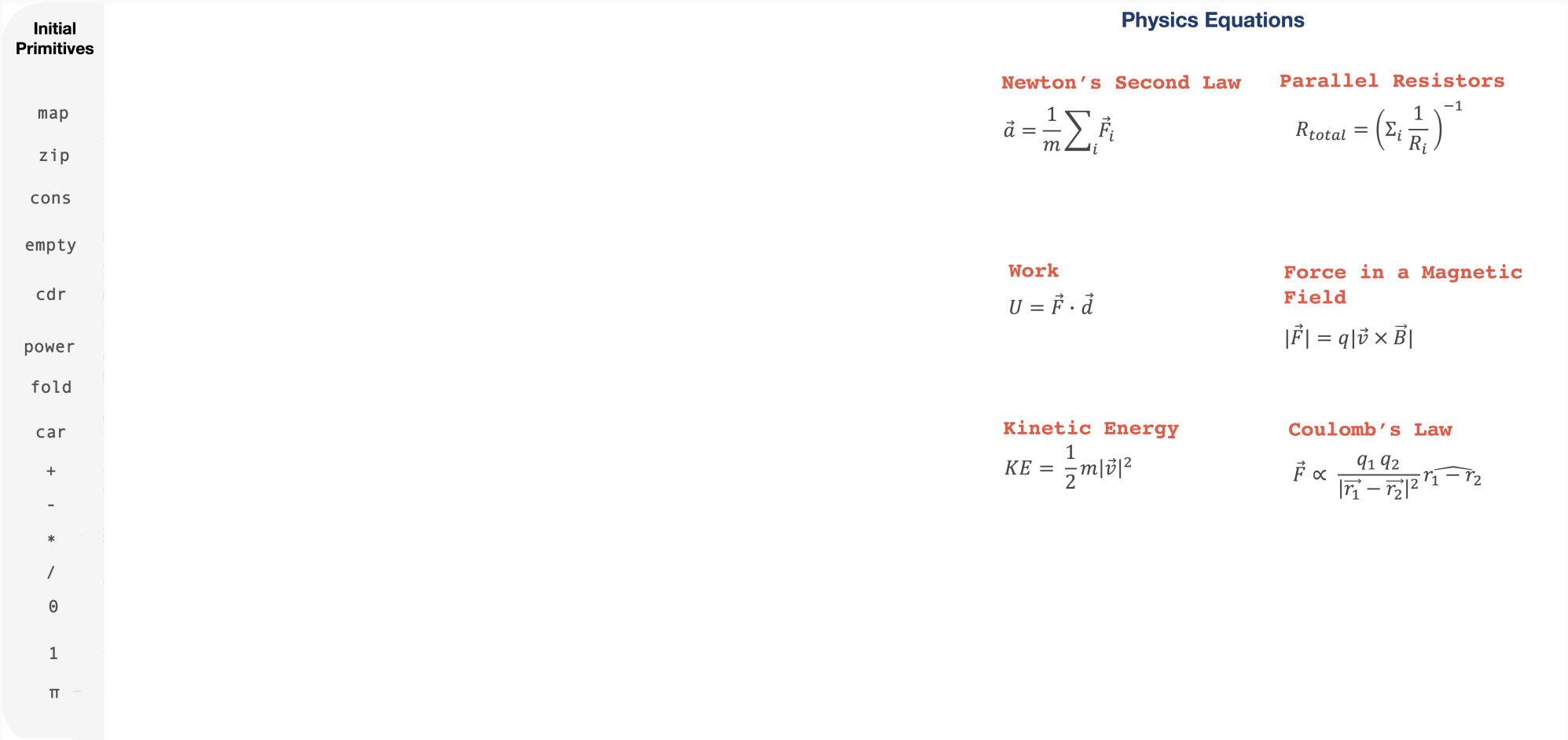
$c^2 = a^2 + b^2$

$\sin\theta = \frac{a}{c}$ $\cos\theta = \frac{b}{c}$ $\tan\theta = \frac{a}{b}$

Variables

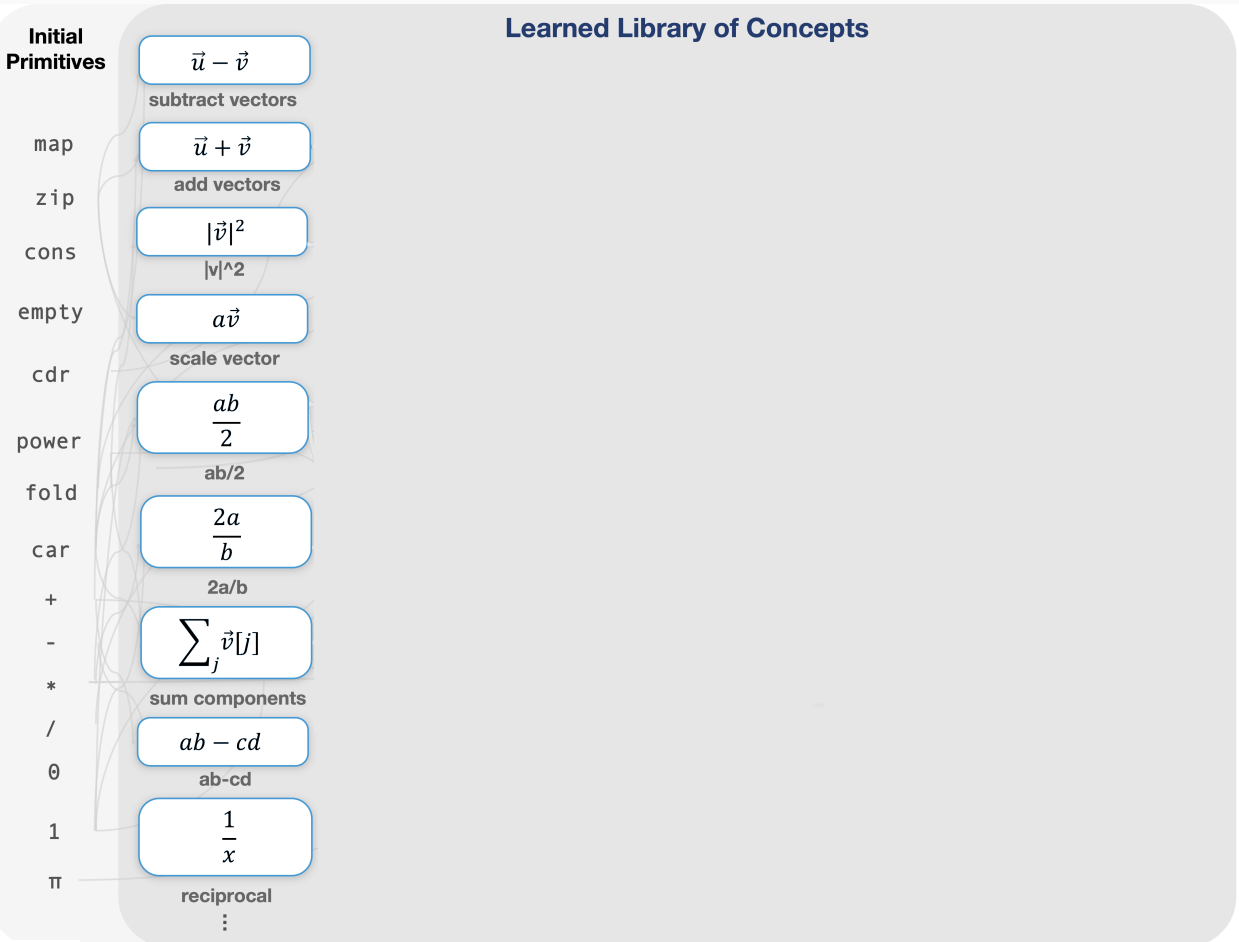
a = acceleration
A = amplitude
A = Area
b = base length
C = circumference
d = distance
E = energy
f = frequency
F = force
h = height
I = current
I = rotational inertia
KE = kinetic energy
k = spring constant
L = angular momentum
ℓ = length
m = mass
P = power
p = momentum
q = charge
r = radius
R = resistance
S = surface area
T = period
t = time
PE = potential energy
V = electric potential
V = volume
v = velocity
w = width
W = work
x = position
y = height
α = angular acceleration
λ = wavelength
μ = coefficient of friction

Growing languages for vector algebra and physics



Ellis, Wong, Nye, ..., Solar-Lezama, Tenenbaum. arxiv 2020.

Growing languages for vector algebra and physics



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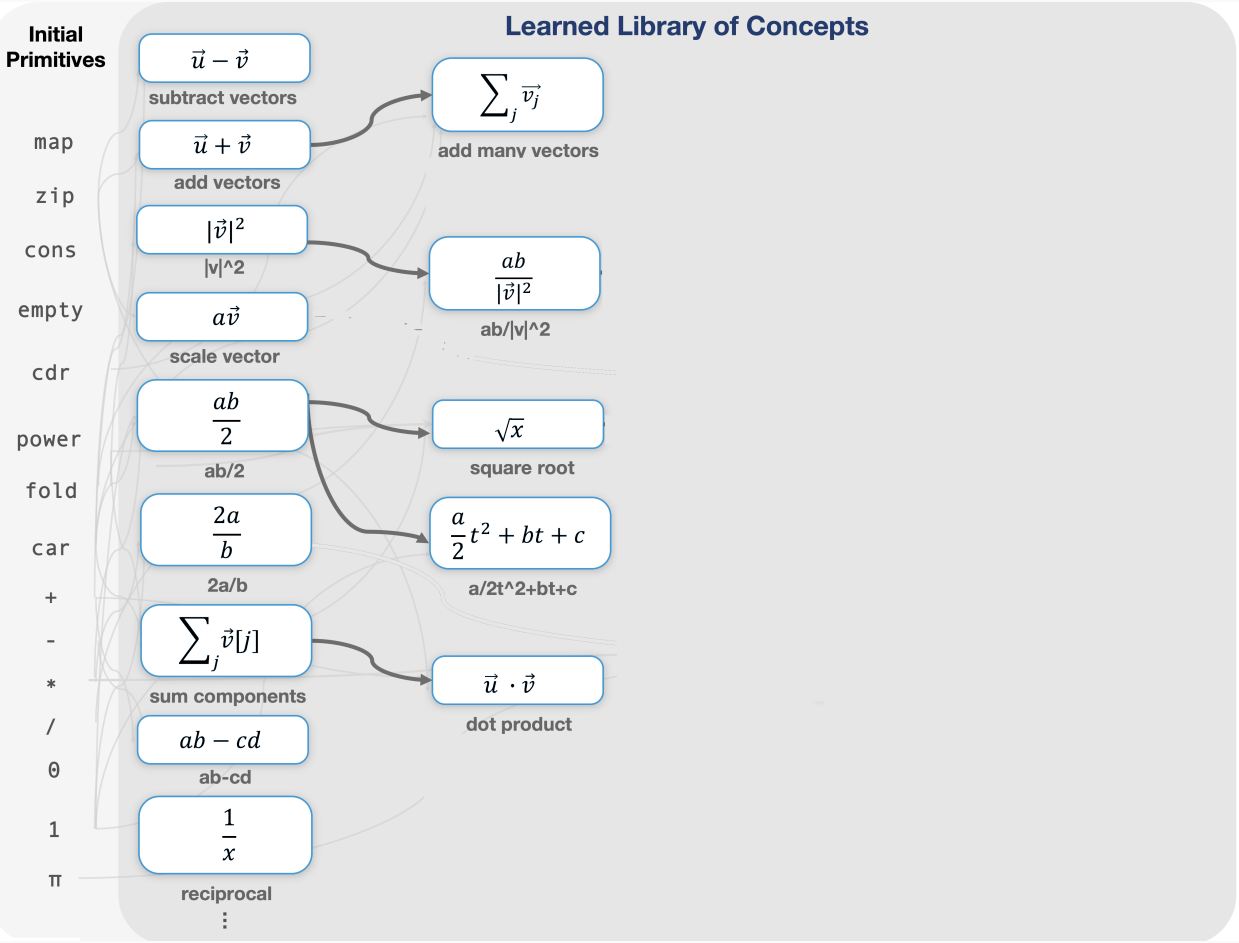
Growing languages for vector algebra and physics



Physics Equations

Newton's Second Law

$$\vec{a} = \frac{1}{m}\sum_i \vec{F}_i$$

Parallel Resistors

$$R_{total} = \left(\Sigma_i \frac{1}{R_i}\right)^{-1}$$

Work

$$U = \vec{F} \cdot \vec{d}$$

Force in a Magnetic Field

$$|\vec{F}| = q|\vec{v} \times \vec{B}|$$

Kinetic Energy

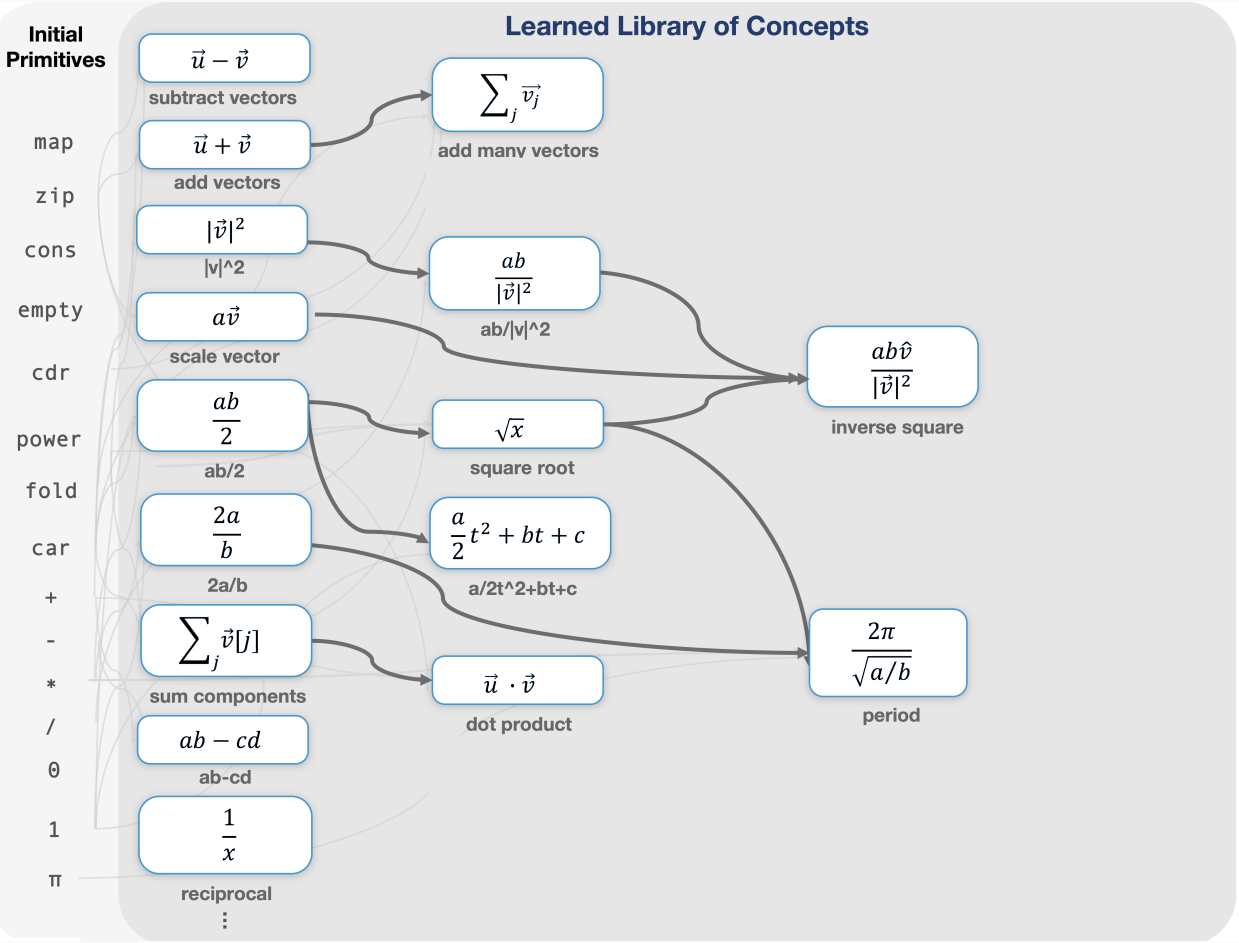
$$KE = \frac{1}{2}m|\vec{v}|^2$$

Coulomb's Law

$$\vec{F} \propto \frac{q_1 q_2}{|\vec{r_1} - \vec{r_2}|^2}\widehat{r_1 - r_2}$$

Ellis, Wong, Nye, ..., Solar-Lezama, Tenenbaum. arxiv 2020.

Growing languages for vector algebra and physics



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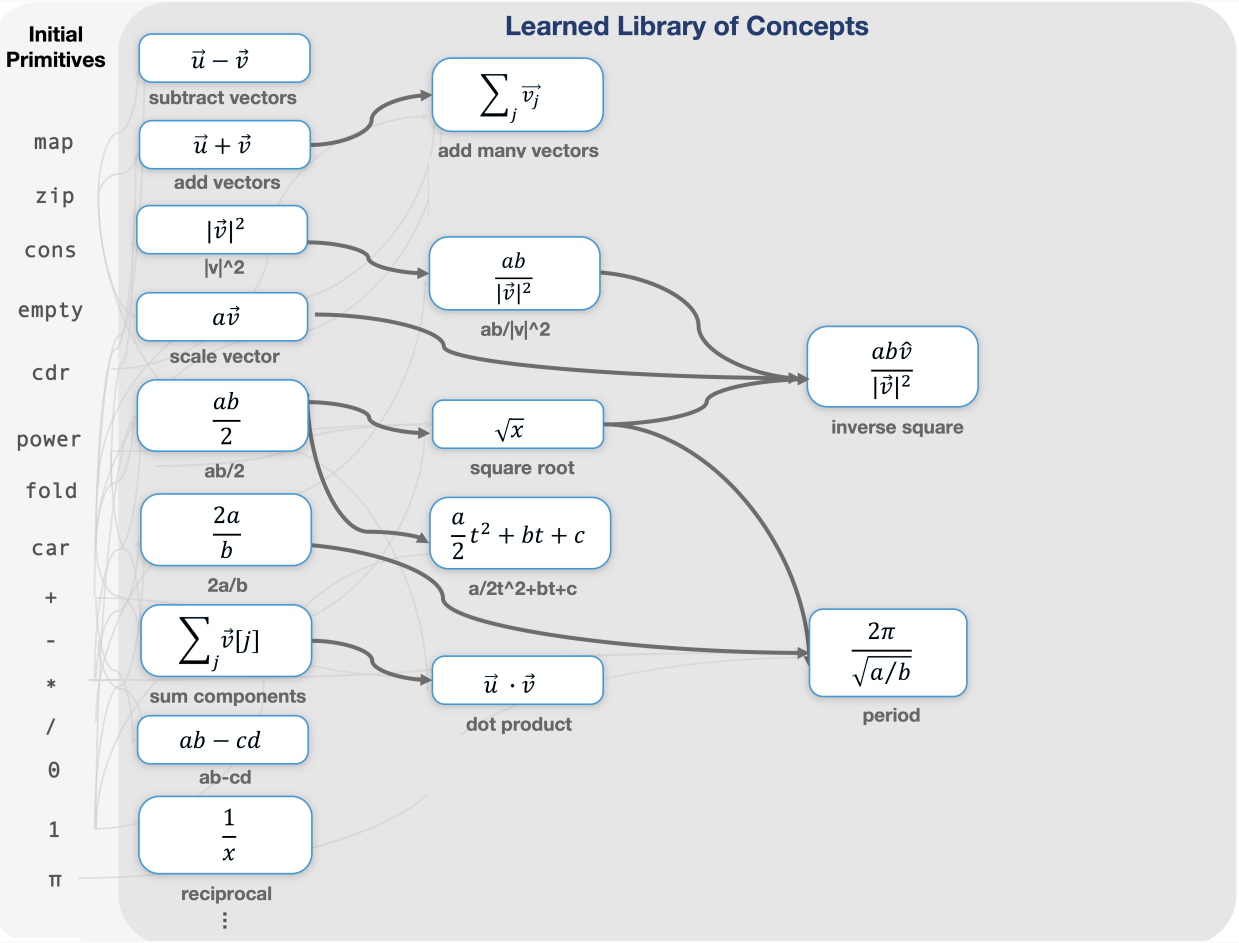
Ellis, Wong, Nye, ..., Solar-Lezama, Tenenbaum. arxiv 2020.

Growing languages for vector algebra and physics



Physics Equations

Newton's Second Law

$$\vec{a}=\frac{1}{m}\sum_i \vec{F}_i$$

```
(scale-vector(reciprocal m)
(add-many-vectors Fs))
```

Parallel Resistors

$$R_{total}=\left(\Sigma_i \frac{1}{R_i}\right)^{-1}$$

```
(reciprocal (sum-components
(map (λ(r) (reciprocal r))
Rs)))
```

Work

$$U=\vec{F}\cdot\vec{d}$$

```
(dot-product F d)
```

Force in a Magnetic Field

$$|\vec{F}|=q|\vec{v}\times\vec{B}|$$

```
(* q (ab-cd v_x b_y v_y b_x))
```

Kinetic Energy

$$KE=\frac{1}{2}m|\vec{v}|^2$$

```
(ab/2 m (|v|^2 v))
```

Coulomb's Law

$$\vec{F}\propto\frac{q_1 q_2}{|\vec{r_1}-\vec{r_2}|^2}\widehat{r_1-r_2}$$

```
(inverse-square q_1 q_2
(subtract-vectors r_1 r_2))
```

Ellis, Wong, Nye, ..., Solar-Lezama, Tenenbaum. arxiv 2020.

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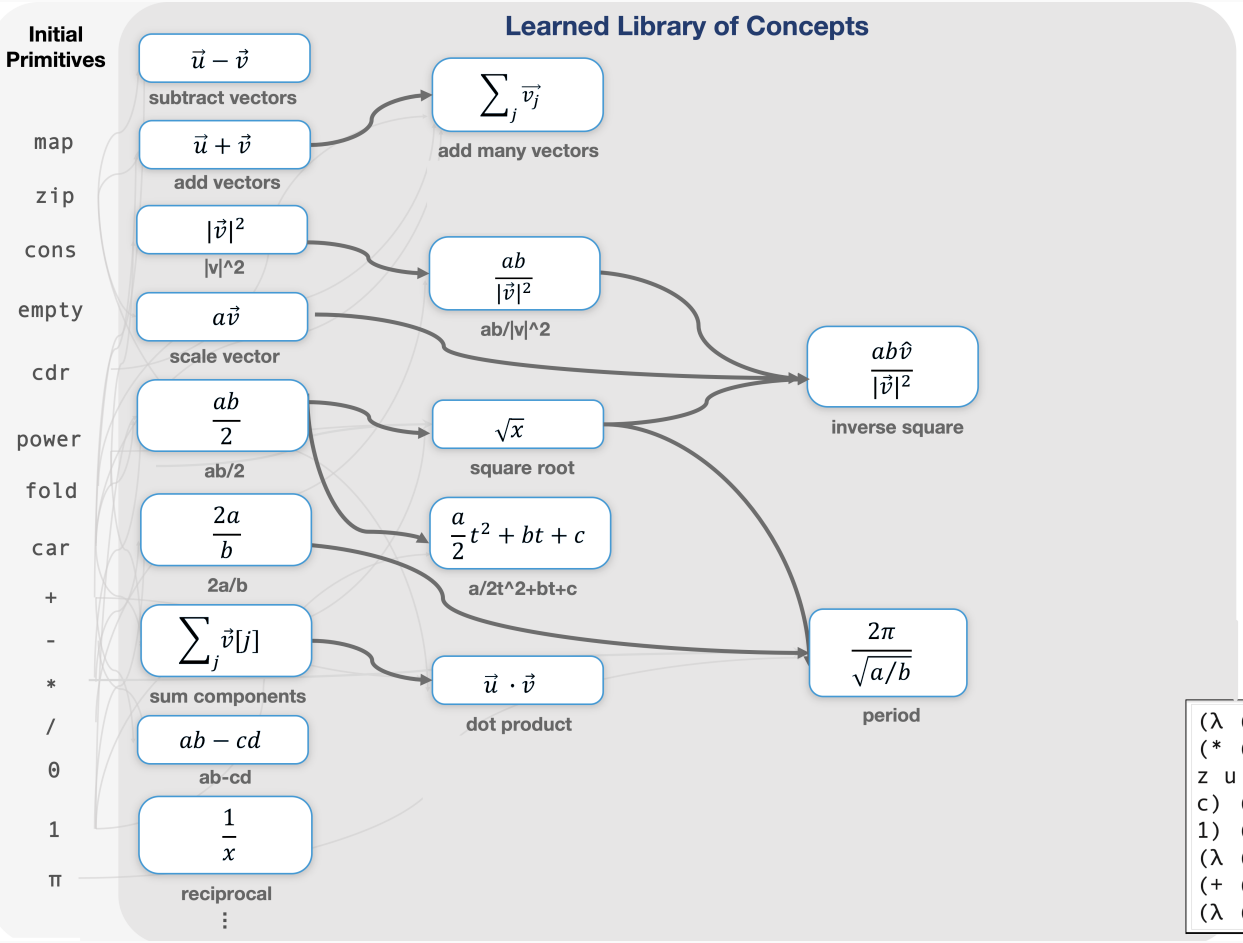

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```
(inverse-square q_1 q_2
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```

```
(λ (x y z u) (map (λ (v) (* (/
(* (power (/ (* x x) (fold (zip
z u (λ (w a) (- w a))) 0 (λ (b
c) (+ (* b b)    c)))) (/ (* 1
1) (+ 1 1))) y) (fold (zip z u
(λ (d e)  (- d e))) 0 (λ (f g)
(+ (* f f) g)))) v)) (zip z u
(λ (h i) (- h i)))))
```

Solution to Coulomb's Law if expressed in initial primitives

Ellis, Wong, Nye, ..., Solar-Lezama, Tenenbaum. arxiv 2020.

Growing a language for recursive programming

Initial Primitives

Y combinator

cons

car

cdr

nil

if

nil?

+

-

0

1

=

Recursive Programming Algorithms

Stutter

[■■] → [■■■■]
[■■■] → [■■■■■■]

Take every other

[■■■■] → [■■]
[■■■■■■] → [■■■]

List lengths

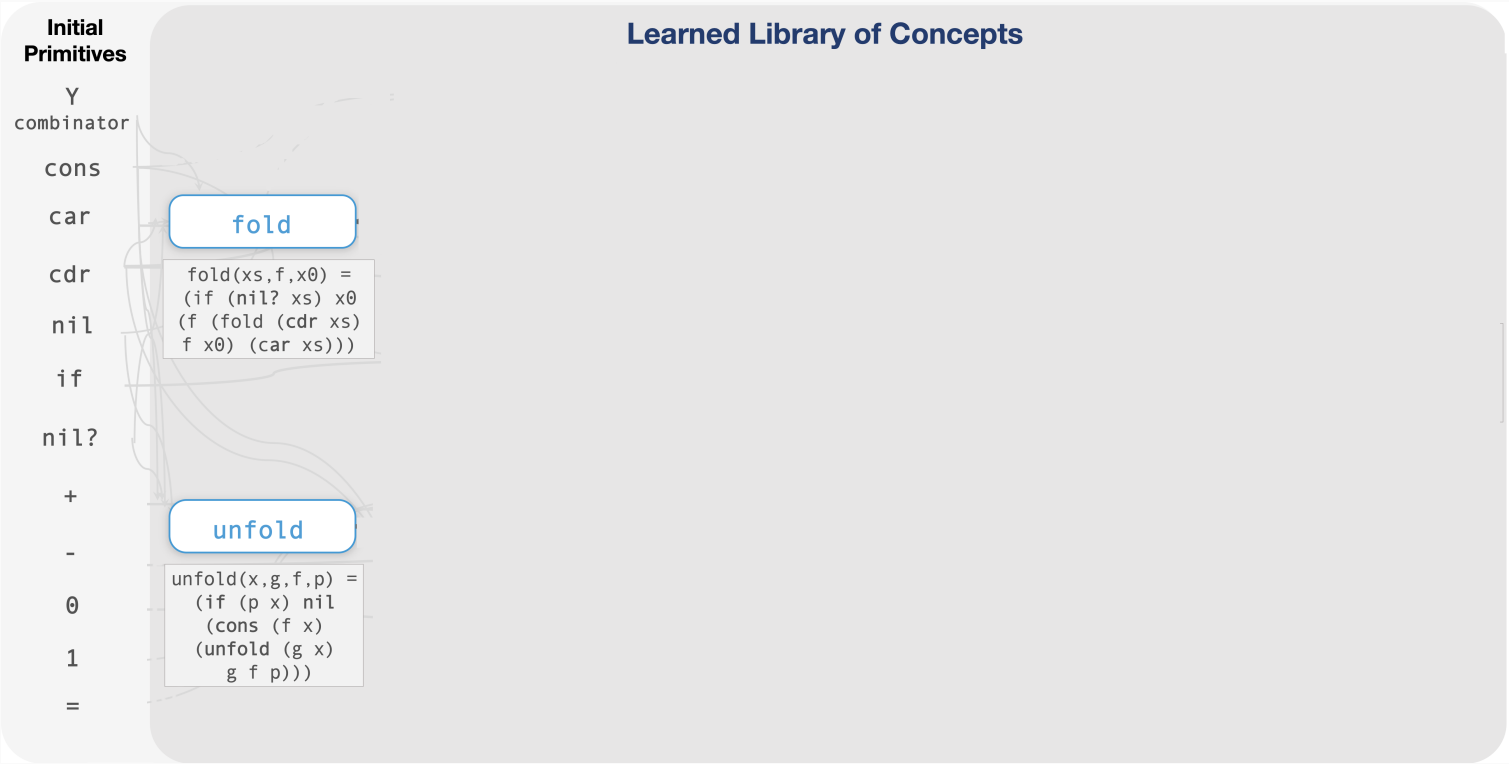
[[■■■], [■]] → [3 1]
[[■■], [], [■]] → [2 0 1]

List differences

[1 8 2], [0 5 1] → [1 3 1]
[2 3 6], [1 2 4] → [1 1 2]

Ellis, Wong, Nye, ..., Solar-Lezama, Tenenbaum. arxiv 2020.

Growing a language for recursive programming



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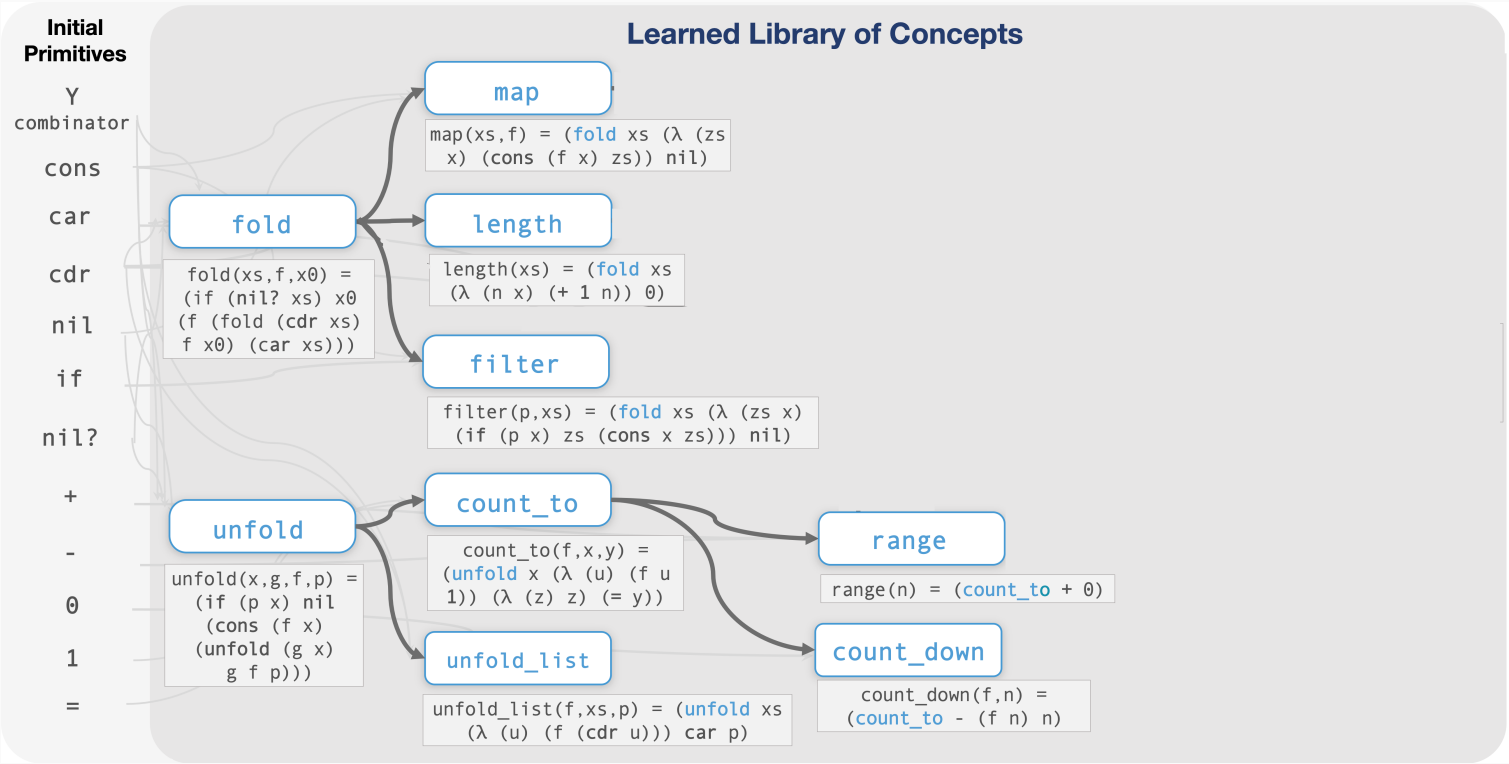

Recursive Programming Algorithms

Stutter

[■■] → [■■■■]
[■■■] → [■■■■■■]

```
(fold A (λ (u v) (cons
v (cons v u))) nil)
```

Take every other

[■■■■] → [■■]
[■■■■■■] → [■■■]

```
(unfold_list cdr A nil?)
```

List lengths

[[■■■], [■]] → [3 1]
[[■■], [], [■]] → [2 0 1]

```
(map A length)
```

List differences

[1 8 2], [0 5 1] → [1 3 1]
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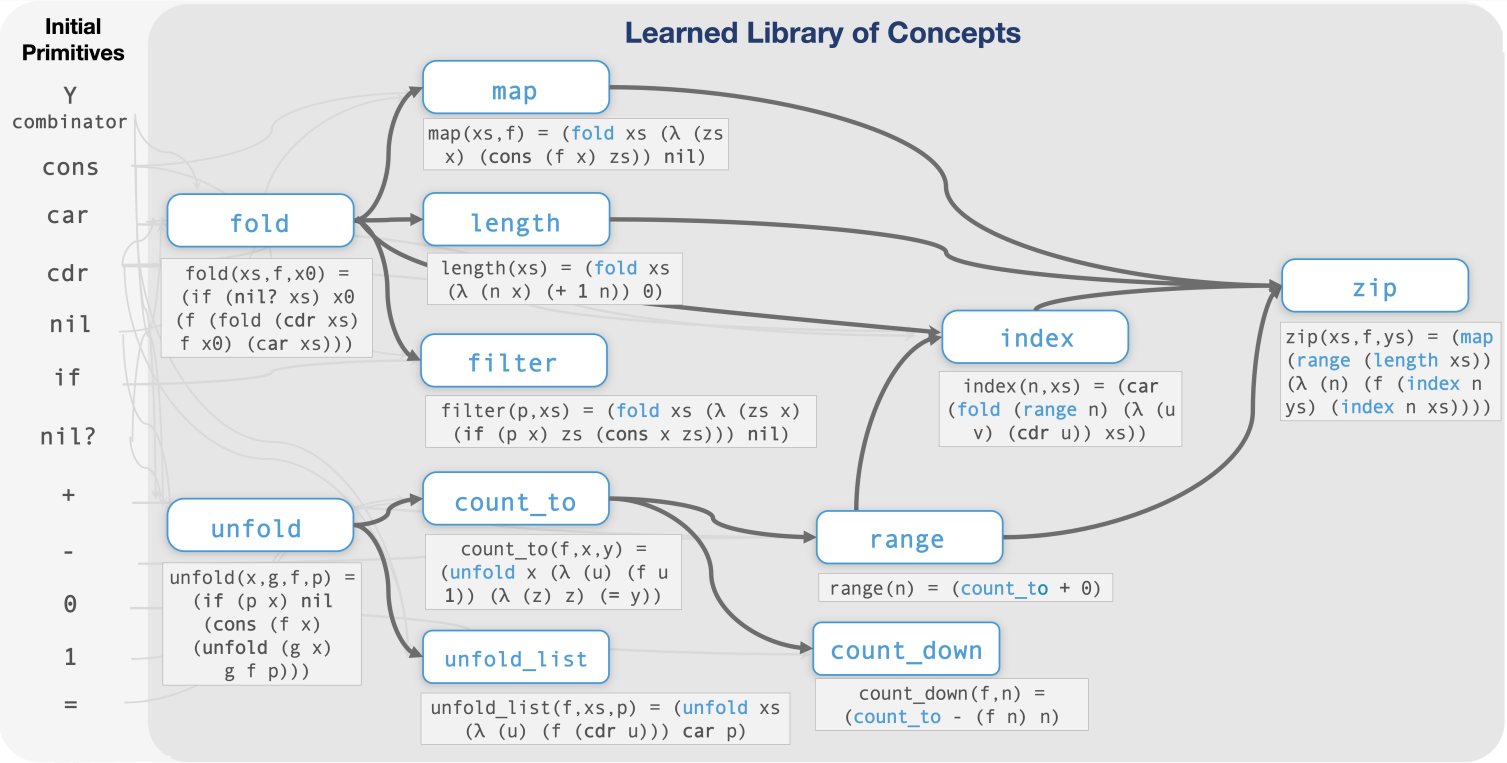

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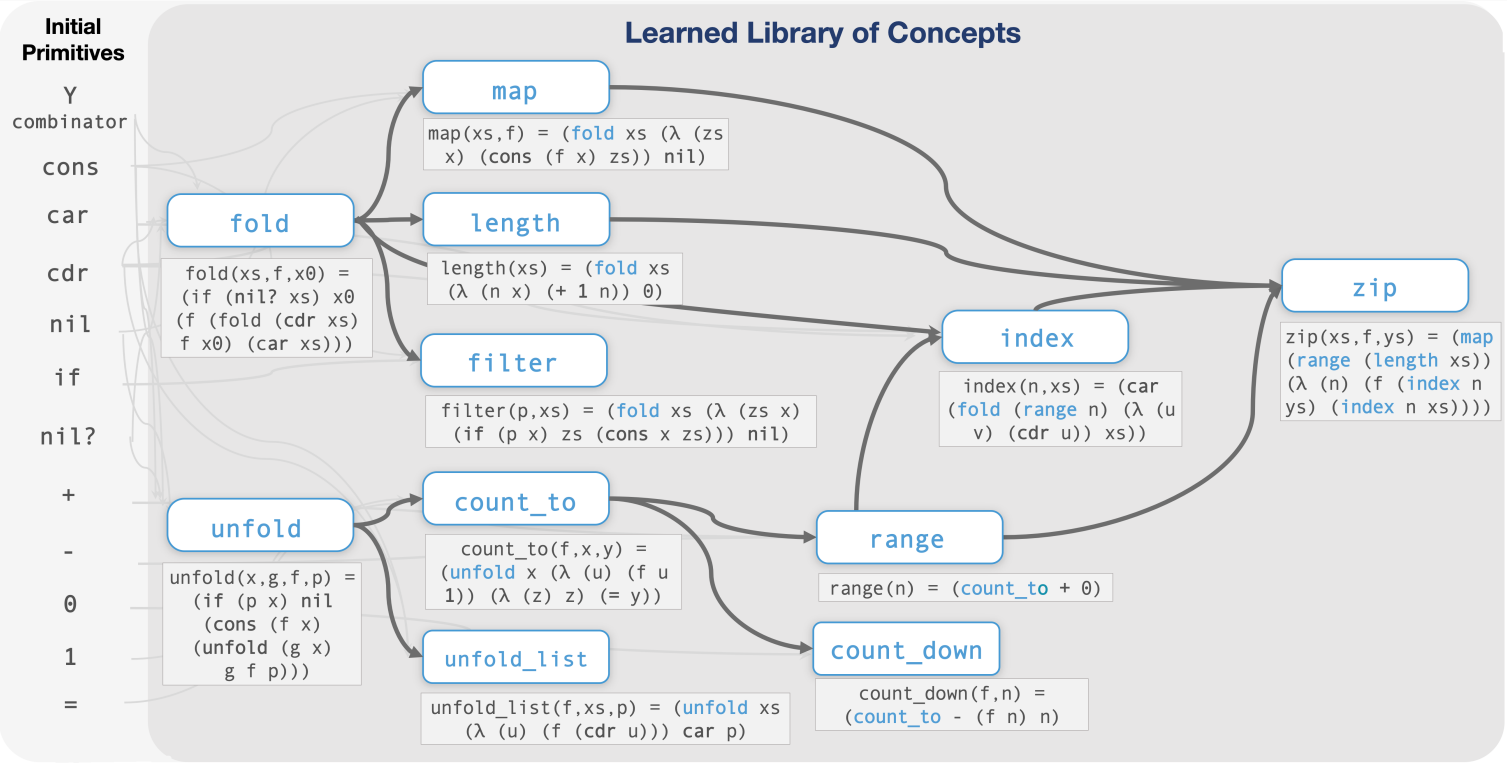

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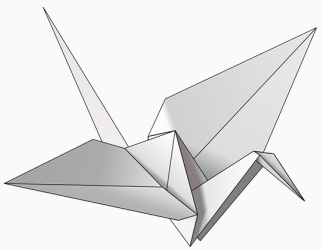
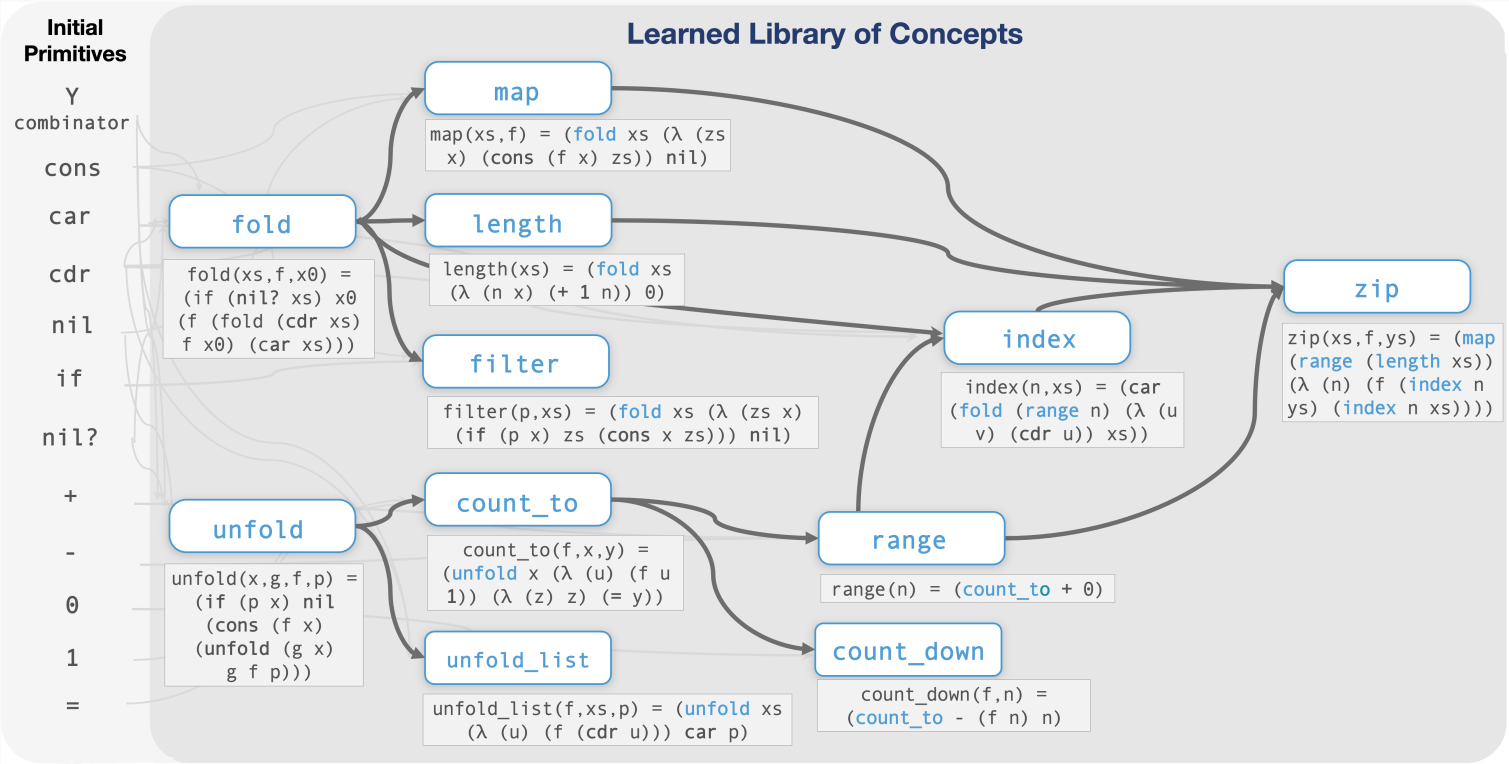


Origami Programming: Jeremy Gibbons, 2003

Ellis, Wong, Nye, ..., Solar-Lezama, Tenenbaum. arxiv 2020.

Growing a language for recursive programming



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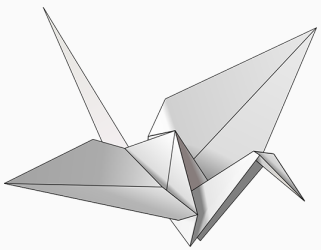
1 year of compute. 5 days on 64 CPUs.



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Lessons

Library learning interacts synergistically with neural synthesis: bootstrapping, more than sum of parts

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Symbols aren't necessarily interpretable. Grow the language based on experience to make it more powerful *and* more human understandable

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Library learning interacts synergistically with neural synthesis: bootstrapping, more than sum of parts

Symbols aren't necessarily interpretable. Grow the language based on experience to make it more powerful *and* more human understandable

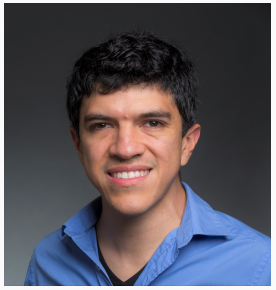
Learning-from-scratch is possible in principle. Don't do it. But program induction makes it convenient to build in what we know how to build in, and then learn on top of that

the end.

Collaborators

Josh Tenenbaum

Armando Solar-Lezama



Max Nye

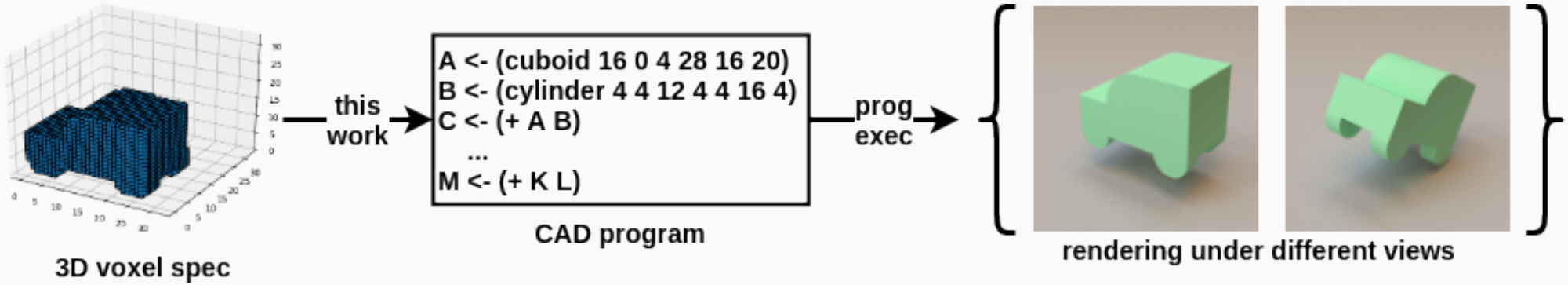
Cathy Wong

Mathias Sable-Meyer

Lucas Morales

thank you

3D program induction



Challenge: combinatorial search!

Branching factor: > 1.3 million per line of code, ≈ 20 lines of code

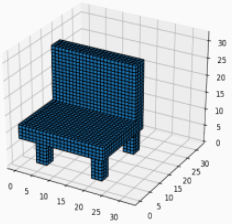
search space size: $(1.3 \text{ million})^{20} \approx 10^{122}$ programs

Ellis*, Nye*, Pu*, Sosa*, Tenenbaum, Solar-Lezama. NeurIPS 2019.

*equal contribution

Solution: stochastic **tree search** + learn **policy** that writes code + learn **value** function that assesses execution of program so far; analogous to **AlphaGo** [Silver et al. 2016]

Input:



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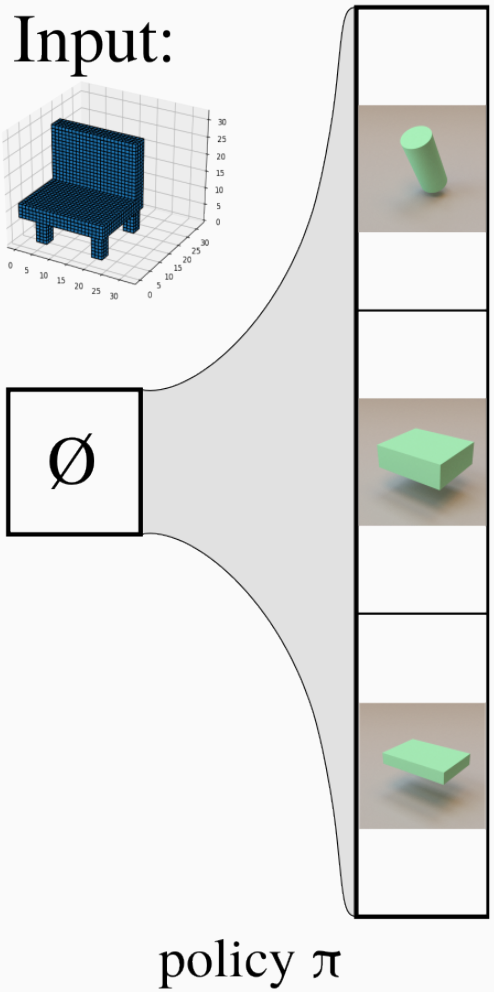

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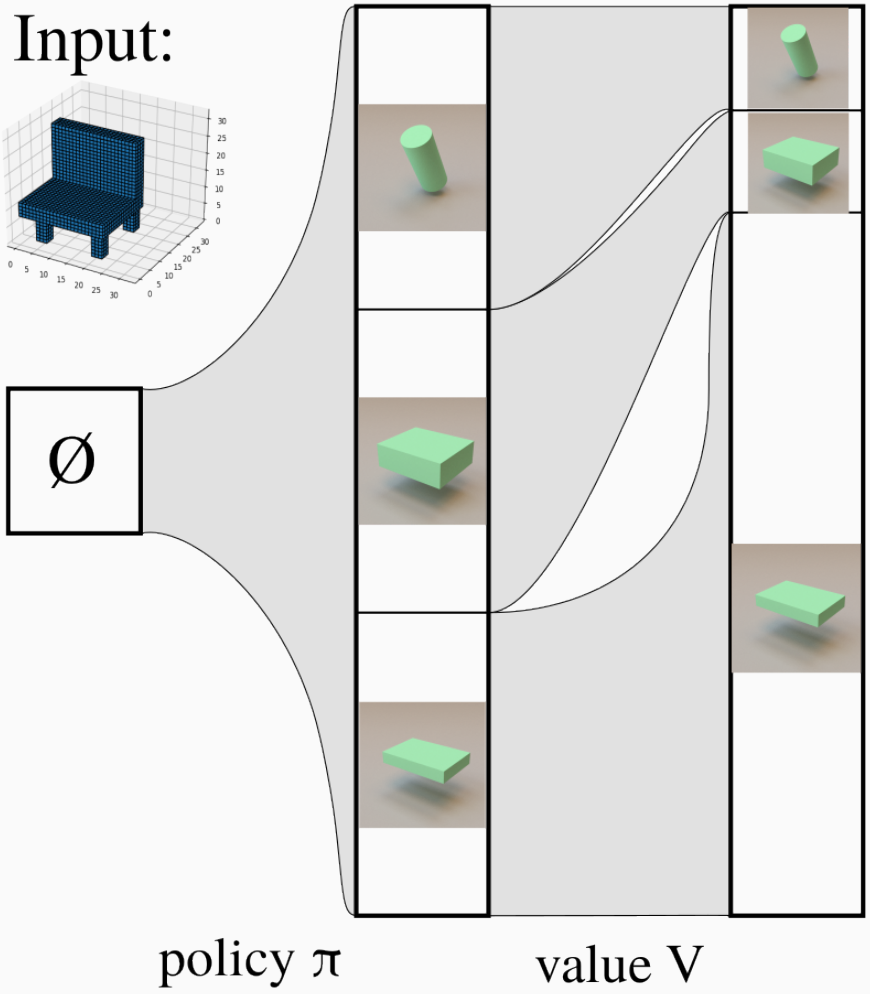

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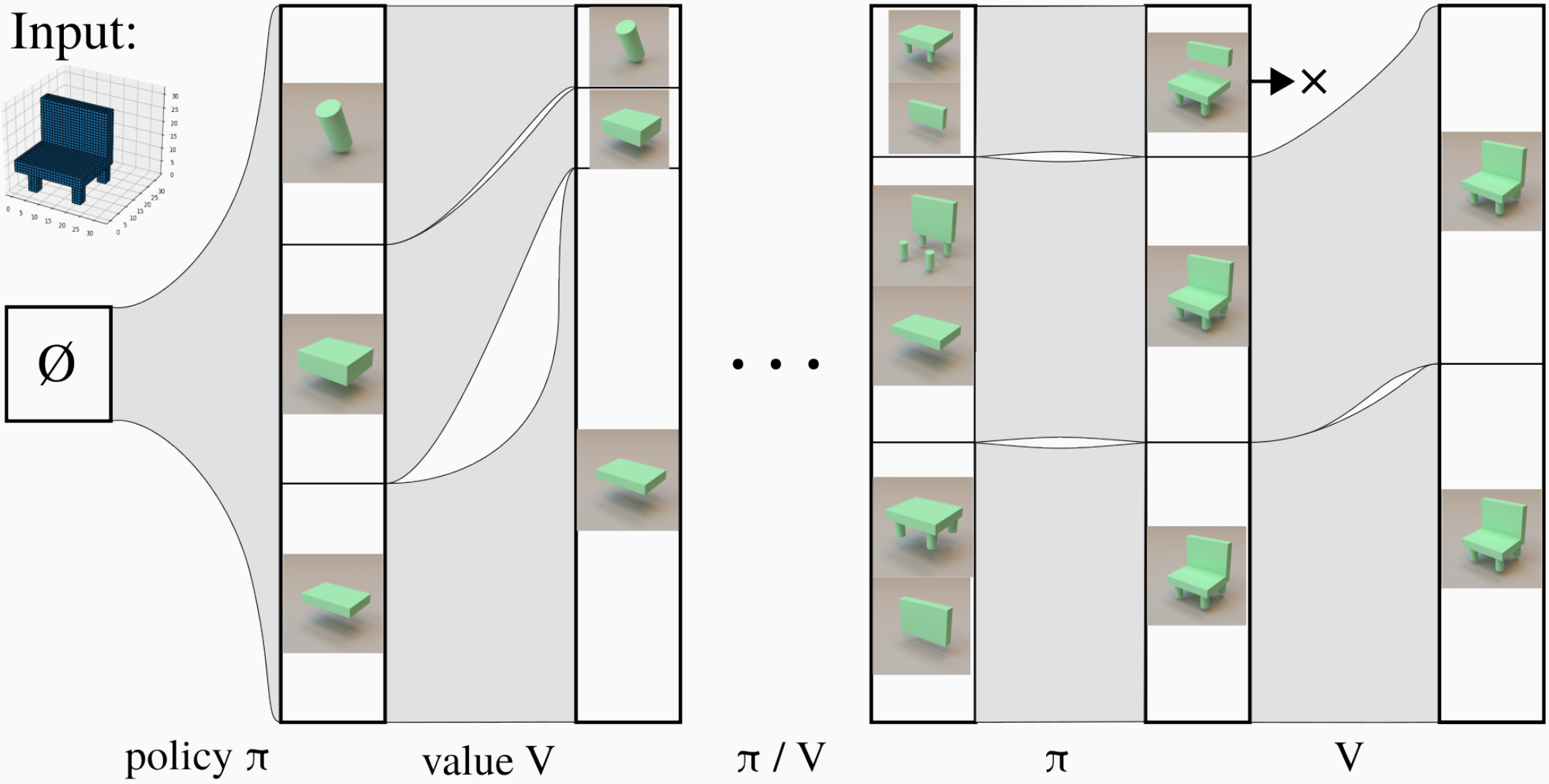
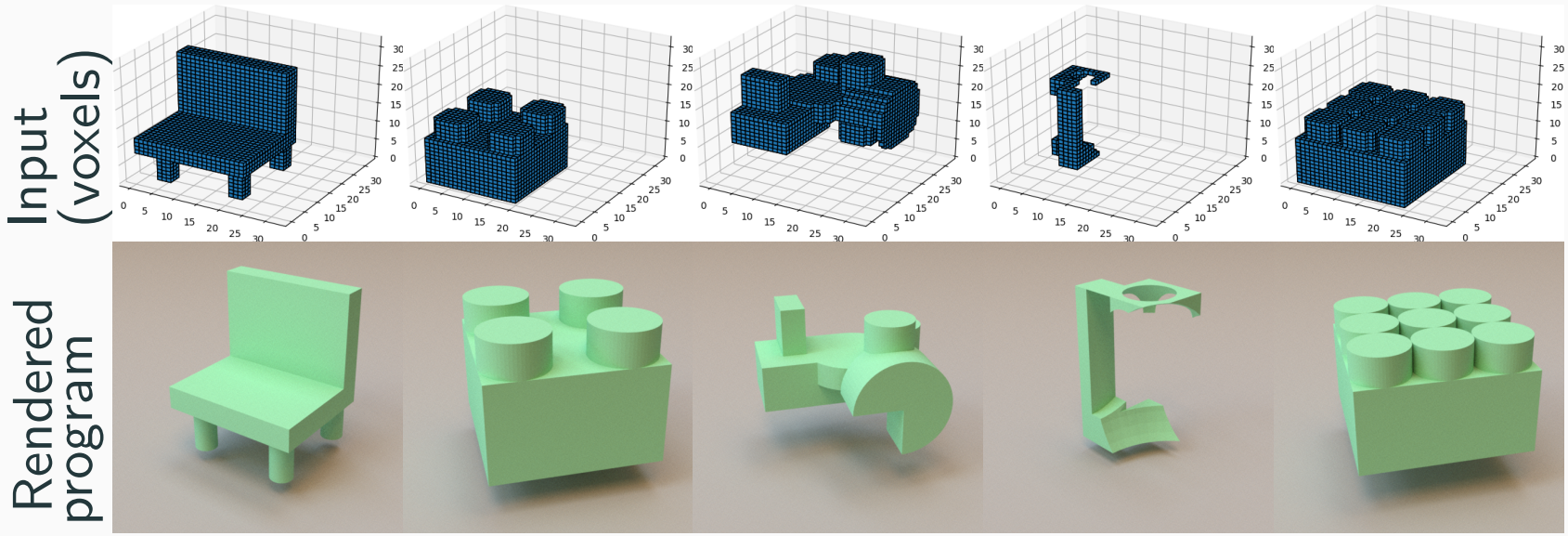


3D program induction



Ellis*, Nye*, Pu*, Sosa*, Tenenbaum, Solar-Lezama. NeurIPS 2019.

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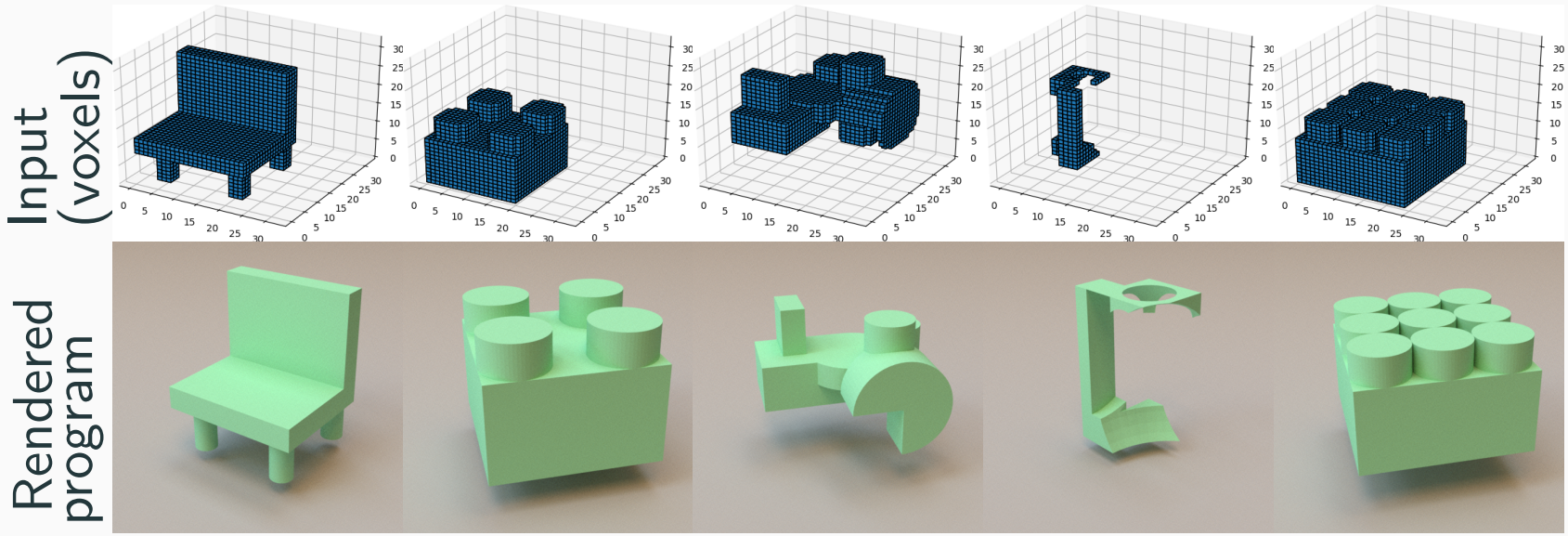
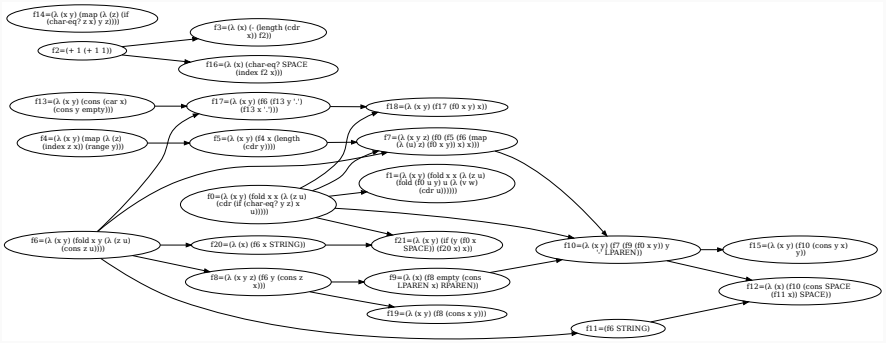


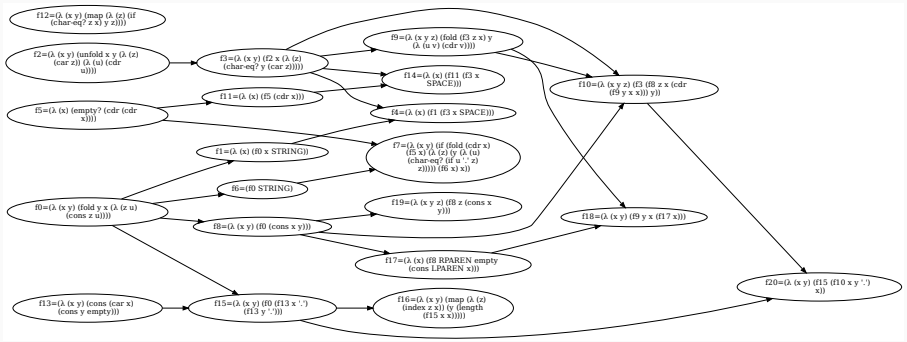
same architecture learns to synthesize text editing programs (FlashFill, Gulwani 2012)

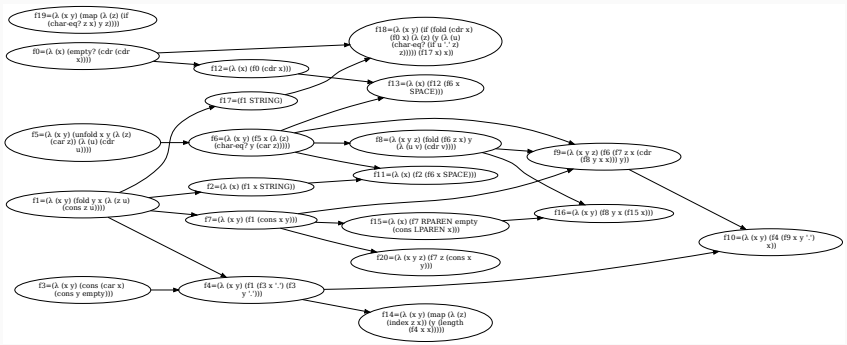
Ellis*, Nye*, Pu*, Sosa*, Tenenbaum, Solar-Lezama. NeurIPS 2019.
*equal contribution

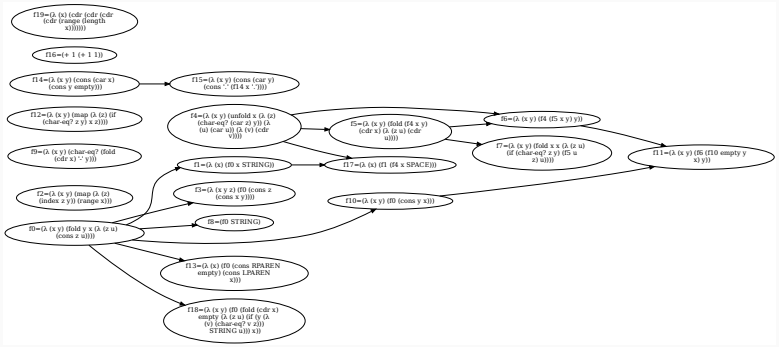
Library structure: Text Editing

DreamCoder learns libraries for FlashFill-style text editing [Gulwani 2012]





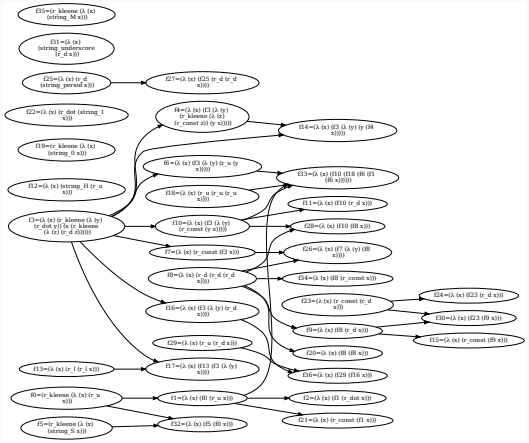


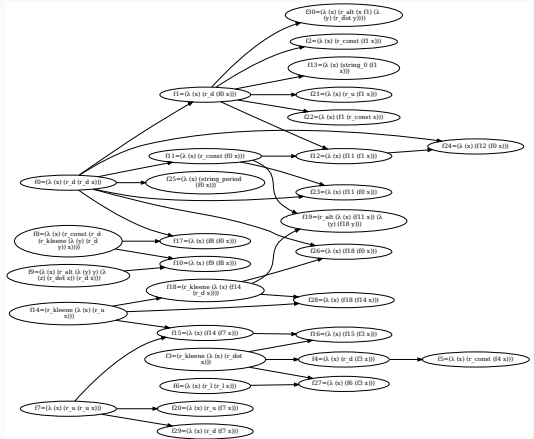


Ellis, Wong, Nye, ..., Solar-Lezama, Tenenbaum. arxiv 2020.

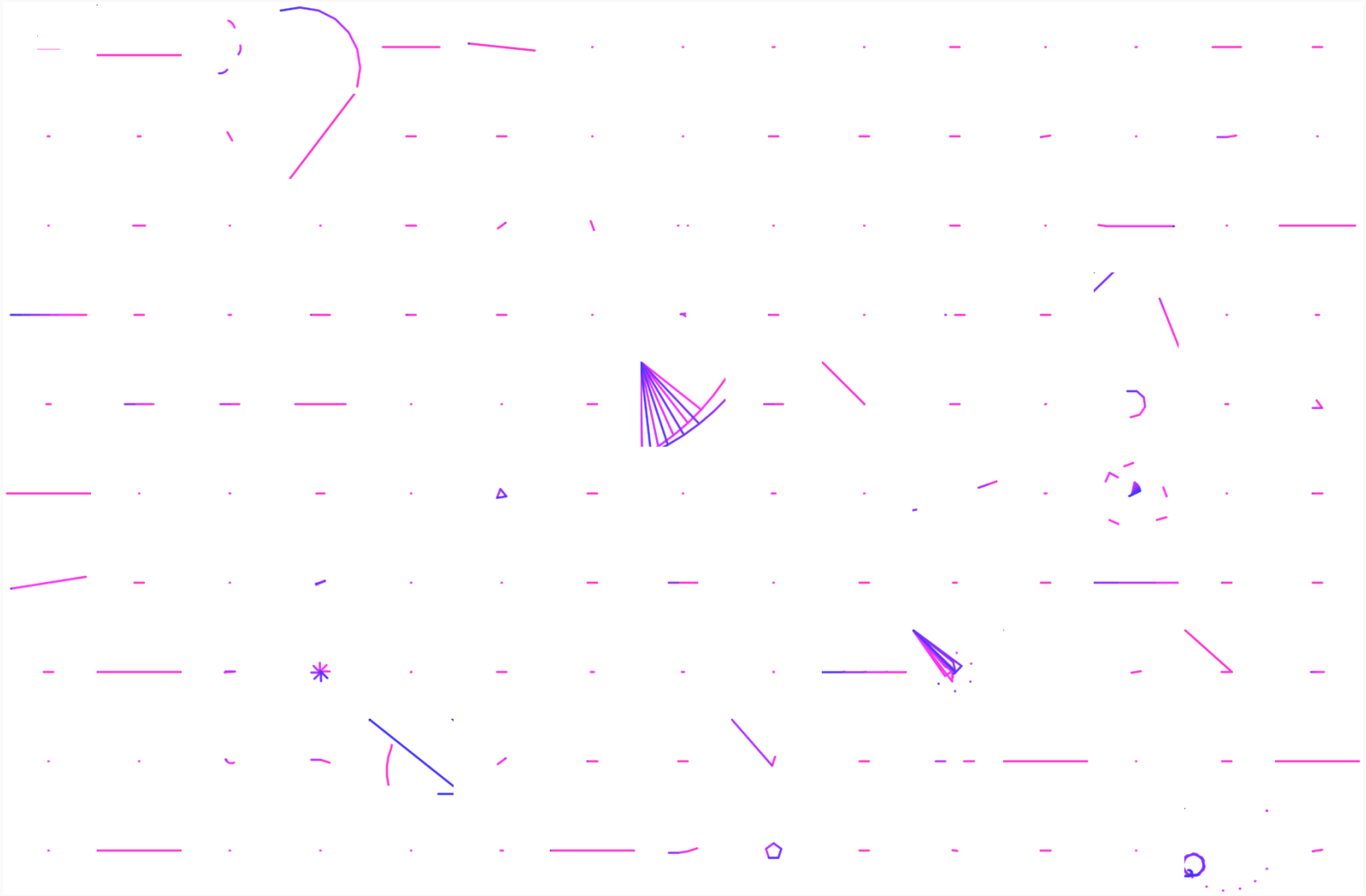
Library structure: Generating Text

Libraries for probabilistic generative models over text:
data from crawling web for CSV files





150 random dreams before learning



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