Learning to Infer Graphics Programs from Hand-Drawn Images

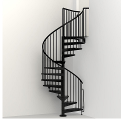
Kevin Ellis[1], Daniel Ritchie[2], Armando Solar-Lezama[1], Joshua B. Tenenbaum[1]

[1]: MIT. [2]: Brown University.

Learning to Infer Graphics Programs from Hand-Drawn Images

Kevin Ellis[1], Daniel Ritchie[2], Armando Solar-Lezama[1], Joshua B. Tenenbaum[1]

[1]: MIT. [2]: Brown University.



Learning to Infer Graphics Programs from Hand-Drawn Images

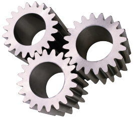
Kevin Ellis[1], Daniel Ritchie[2], Armando Solar-Lezama[1], Joshua B. Tenenbaum[1]

[1]: MIT. [2]: Brown University.

Learning to Infer Graphics Programs from Hand-Drawn Images

Kevin Ellis[1], Daniel Ritchie[2], Armando Solar-Lezama[1], Joshua B. Tenenbaum[1]

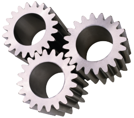
[1]: MIT. [2]: Brown University.

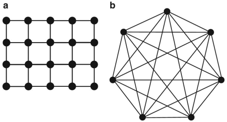


Learning to Infer Graphics Programs from Hand-Drawn Images

Kevin Ellis[1], Daniel Ritchie[2], Armando Solar-Lezama[1], Joshua B. Tenenbaum[1]

[1]: MIT. [2]: Brown University.

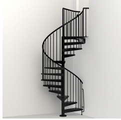


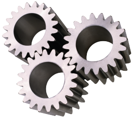


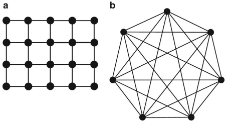
Learning to Infer Graphics Programs from Hand-Drawn Images

Kevin Ellis[1], Daniel Ritchie[2], Armando Solar-Lezama[1], Joshua B. Tenenbaum[1]

[1]: MIT. [2]: Brown University.

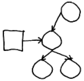


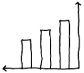


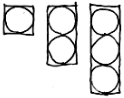


Hand Drawing **Program**

Drawing

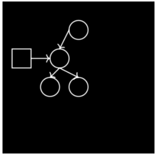


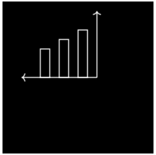


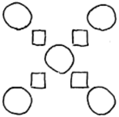


```
for (i < 3)
 rectangle(3*i,-2*i+4,
           3*i+2,6)
 for (j < i + 1)
  circle(3*i+1,-2*j+5)
```

LaTeX







```
reflect(y=8)
 for(i<3)
  if(i>0)
   rectangle(3*i-1,2,3*i,3)
  circle(3*i+1,3*i+1)
```

Image→Program Pipeline

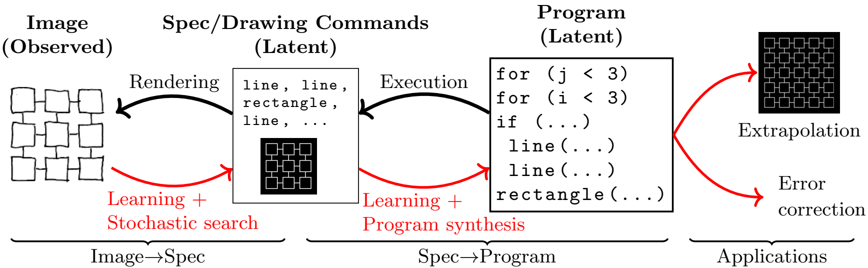


Image (Observed)

Spec/Drawing Commands (Latent)

Program (Latent)

Rendering

Execution

```
line, line,
rectangle,
line, ...
```

```
for (j < 3)
for (i < 3)
if (...)
 line(...)
 line(...)
rectangle(...)
```

Learning + Stochastic search

Learning + Program synthesis

Extrapolation

Error correction

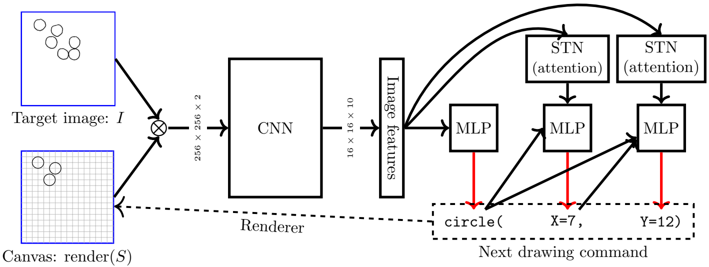
Image→Spec

Spec→Program

Applications

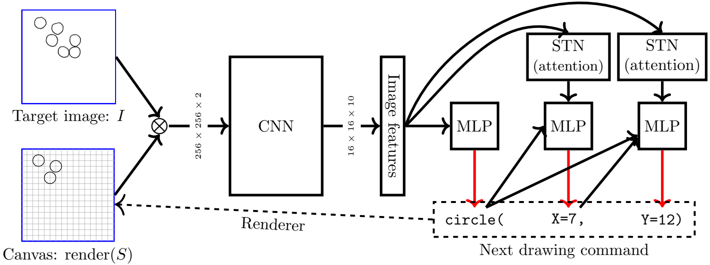
Parsing images into LATEX TikZ Commands

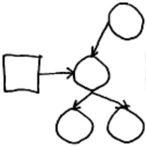
Neurally Guided Procedural Modeling (Ritchie et al 2016) + Attend, Infer, Repeat (Eslami et al 2016)



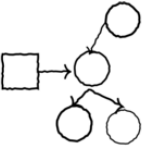
Parsing images into LaTeX TikZ Commands

Neurally Guided Procedural Modeling (Ritchie et al 2016) + Attend, Infer, Repeat (Eslami et al 2016)





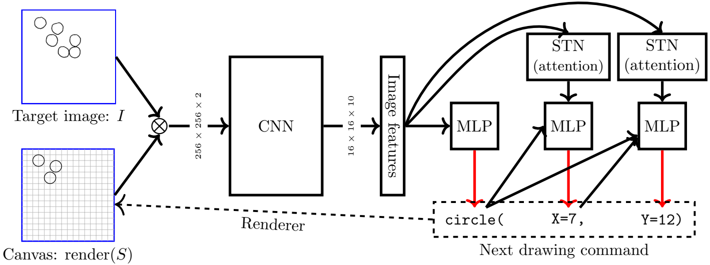
(a): hand drawing

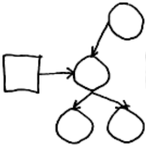


(b): noisy render of (a)'s spec

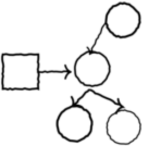
Parsing images into LaTeX TikZ Commands

Neurally Guided Procedural Modeling (Ritchie et al 2016) + Attend, Infer, Repeat (Eslami et al 2016)

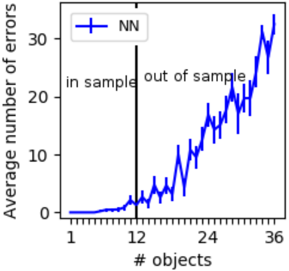




(a): hand drawing

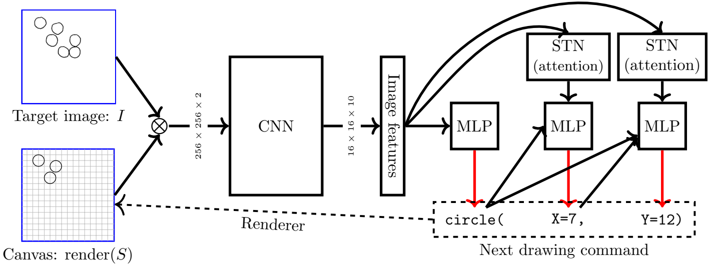


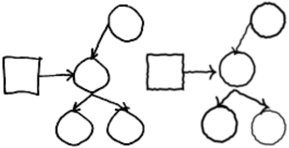
(b): noisy render of (a)'s spec



Parsing images into LaTeX TikZ Commands

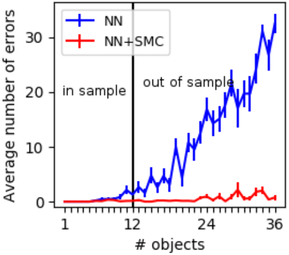
Neurally Guided Procedural Modeling (Ritchie et al 2016) + Attend, Infer, Repeat (Eslami et al 2016)





(a): hand drawing

(b): noisy render of (a)'s spec



Synthesizing high-level programs from specs (spec=drawing commands)

Constraint-based program synthesis; SAT solver (Solar-Lezama 2008)

$$\text{program}(S) = \underset{\substack{p\in\text{DSL}\\ p\text{ consistent w/ }S}}{\arg\min}\quad \text{cost}(p)$$

min cost≈simple+short

DSL: **D**omain **S**pecific **L**anguage: variables, arithmetic, loops, conditionals

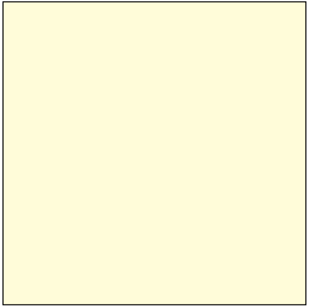
Program→	Statement; $\cdots$; Statement
Statement→	`circle`(Expression,Expression)
Statement→	`rectangle`(Expression,Expression,Expression,Expression)
Statement→	`line`(Expression,Expression,Expression,Expression,Boolean,Boolean)
Statement→	`for`(0 $\leq$ Var $<$ Expression) { `if` (Var $>$ 0) { Program }; Program }
Statement→	`reflect`(Axis) { Program }
Expression→	$\mathbb{Z}\times$Var+$\mathbb{Z}$
Axis→	`X = ` $\mathbb{Z}$ $\vert$`Y = Z`
$\mathbb{Z}$ →	an integer

Learning to quickly synthesize programs

Learn search policy $\pi(\text{program subspace}|\text{spec})$

Think of the subspace as an “ansatz”

OBJECTIVE: Small subspace for tractability while also being likely to contain good programs



Entire program search space

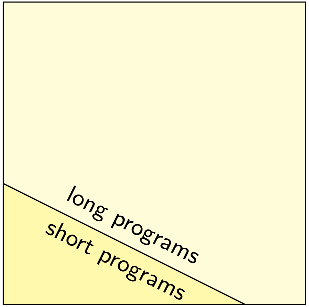
Learning to quickly synthesize programs

Learn search policy π(program subspace|spec)

Think of the subspace as an "ansatz"

OBJECTIVE: Small subspace for tractability while also being likely to contain good programs

Entire program search space



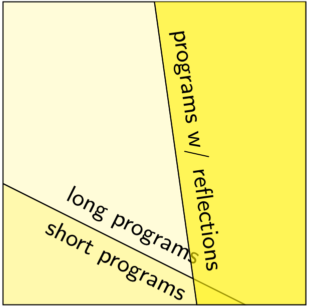
Learning to quickly synthesize programs

Learn search policy $\pi(\text{program subspace}|\text{spec})$

Think of the subspace as an “ansatz”

OBJECTIVE: Small subspace for tractability while also being likely to contain good programs

Entire program search space



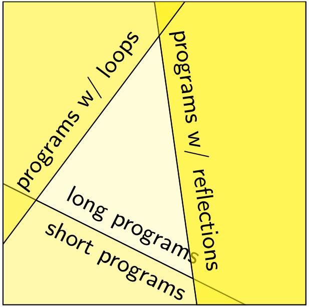
Learning to quickly synthesize programs

Learn search policy π(program subspace|spec)

Think of the subspace as an "ansatz"

OBJECTIVE: Small subspace for tractability while also being likely to contain good programs

Entire program search space



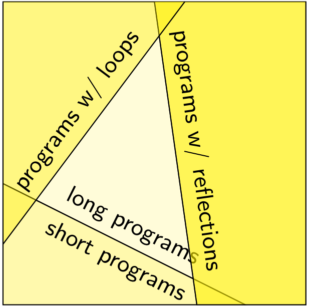
Learning to quickly synthesize programs

Learn search policy $\pi(\text{program subspace}|\text{spec})$

Think of the subspace as an “ansatz”

OBJECTIVE: Small subspace for tractability while also being likely to contain good programs

Entire program search space



$\pi(\text{short, no loop/reflect}|S) =$ 🟨

$\pi(\text{long, loops}|S) =$ 🟨

$\pi(\text{long, no loop/reflect}|S) =$ 🟨

$\pi(\text{long, reflects}|S) =$ 🟨

etc.

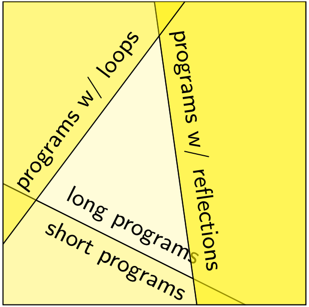
Learning to quickly synthesize programs

Learn search policy π(program subspace|spec)

Think of the subspace as an “ansatz”

OBJECTIVE: Small subspace for tractability while also being likely to contain good programs

Entire program search space



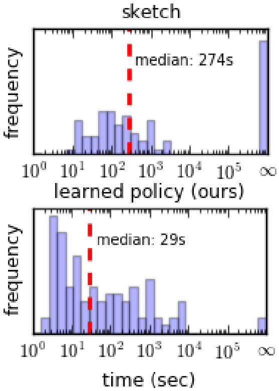
π(short, no loop/reflect$|S$) = 🟨

π(long, loops$|S$) = 🟨

π(long, no loop/reflect$|S$) = 🟨

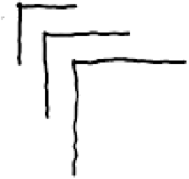
π(long, reflects$|S$) = 🟨

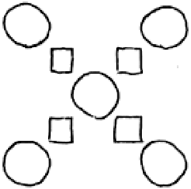
etc.

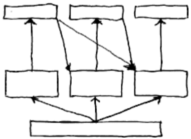


Example programs

Drawing	Spec	Program

	Line(2,15, 4,15)
	Line(4,9, 4,13)
	Line(3,11, 3,14)
	Line(2,13, 2,15)
	Line(3,14, 6,14)
	Line(4,13, 8,13)
		for(i<3)
		 line(i,-1*i+6,
		      2*i+2,-1*i+6)
		 line(i,-2*i+4,i,-1*i+6)

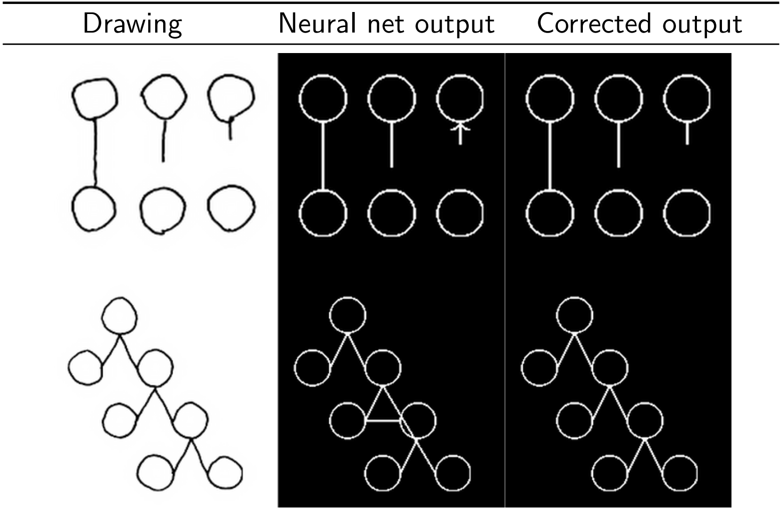
	Circle(2,8)
	Rectangle(6,9, 7,10)
	Circle(8,8)
	Rectangle(6,12, 7,13)
	Rectangle(3,9, 4,10)
	... etc. ...; 9 lines
		reflect(y=8)
		 for(i<3)
		  if(i>0)
		   rectangle(3*i-1,2,3*i,3)
		  circle(3*i+1,3*i+1)

	Line(3,10,3,14,arrow)
	Rectangle(11,8,15,10)
	Rectangle(11,14,15,15)
	Line(13,10,13,14,arrow)
	... etc. ...; 16 lines
		for(i<3)
		 line(7,1,5*i+2,3,arrow)
		 for(j<i+1)
		  if(j>0)
		   line(5*j-1,9,5*i,5,arrow)
		  line(5*j+2,5,5*j+2,9,arrow)
		 rectangle(5*i,3,5*i+4,5)
		 rectangle(5*i,9,5*i+4,10)
		rectangle(2,0,12,1)

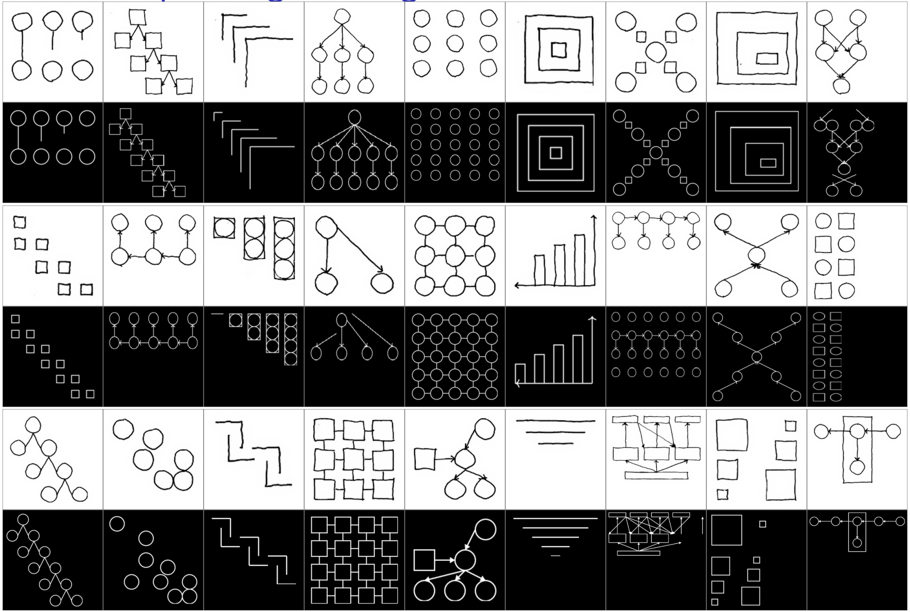
Application: Error correction

learn prior over programs (simple≈better), jointly infer likely parse+program

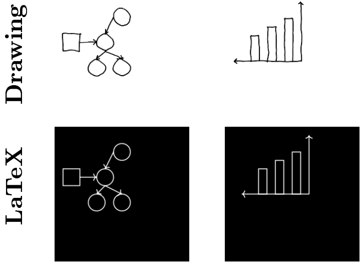
Top-down influence upon perception



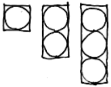
Application: Extrapolating drawings



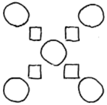
Visual input→Program: Poster AB #25



Hand Drawing **Program**



```
for (i < 3)
 rectangle(3*i,-2*i+4,
           3*i+2,6)
 for (j < i + 1)
  circle(3*i+1,-2*j+5)
```



```
reflect(y=8)
 for(i<3)
  if(i>0)
   rectangle(3*i-1,2,3*i,3)
  circle(3*i+1,3*i+1)
```