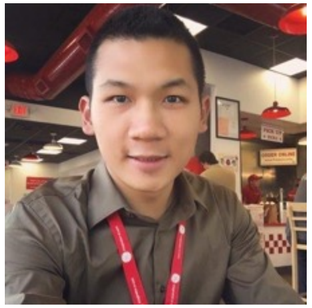
Neural Program Synthesis from Diverse Demonstration Videos



Shao-Hua Sun*[1]

Hyeonwoo Noh*[2]

Sriram Somasundaram[1]

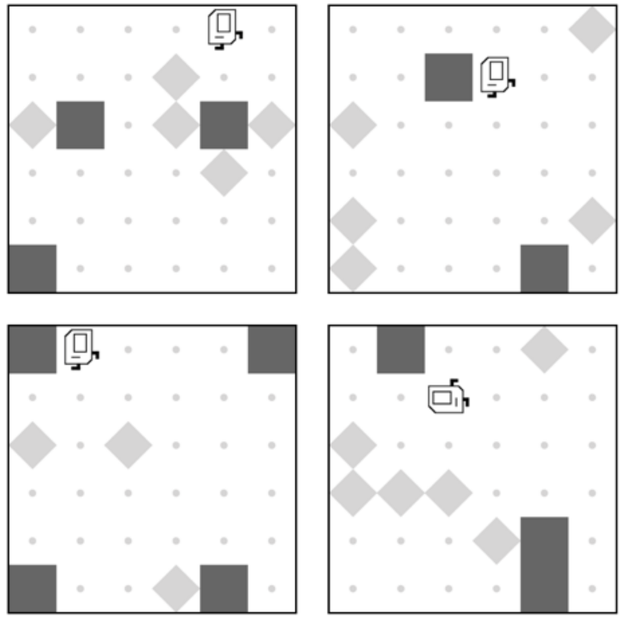
Joseph J. Lim[1]

[1]University of Southern California
[2]Pohang University of Science and Technology
*Equal contribution


youtube.com/croutoncrackerjacks

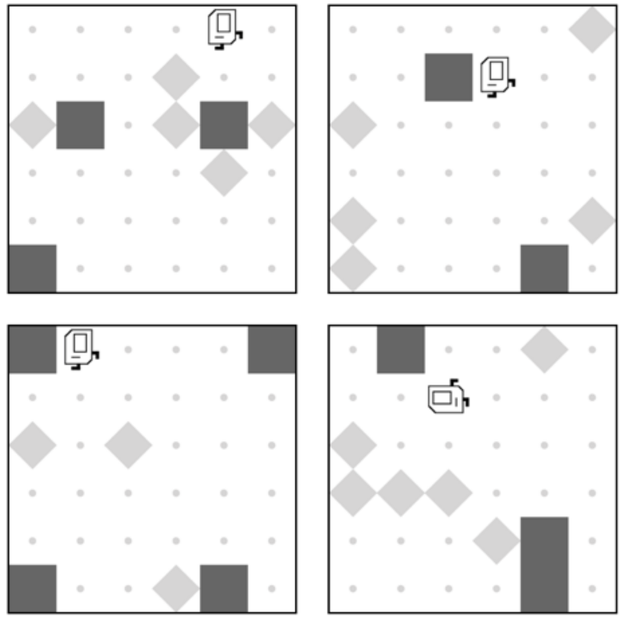

sesame oil
1 tbsp


Oil - 2 tbsp



```
def run()
  if frontIsClear():
    move()
  else:
    turnLeft()
  move()
  turnLeft()
  repeat(2):
    turnRight()
    putMarker()
```

A **program** is an interpretable and executable way to describe behaviors



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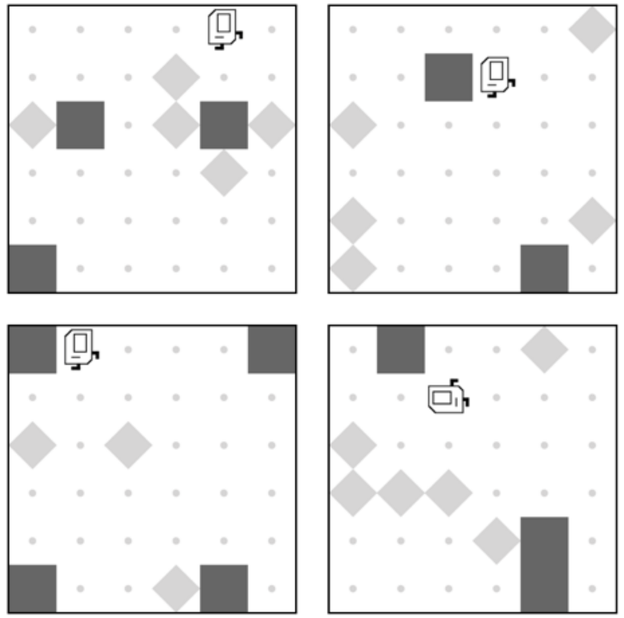
Human

A **program** is an interpretable and executable way to describe behaviors



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    putMarker()
```

Human **Robot**

A **program** is an interpretable and executable way to describe behaviors

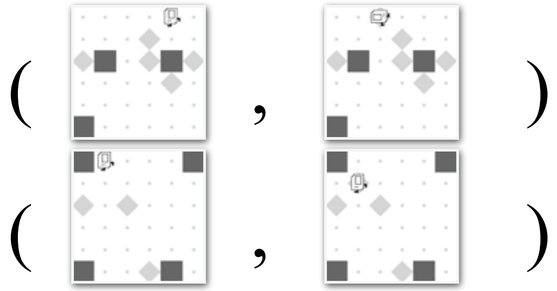
Program Synthesis

```
public class TcpClientSample
{
    public static void Main()
    {
        byte[] data = new byte[1024]; string input, stringData;
        TcpClient server;
        try{
            server = new TcpClient(" . . . . ", port);
        }catch (SocketException){
            Console.WriteLine("Unable to connect to server")
            return;
        }
        NetworkStream ns = server.GetStream();
        int recv = ns.Read(data, 0, data.Length);
        stringData  = Encoding.
            ASCII.GetString(data, 0, recv);
        Console.WriteLine(stringData);
        while(true){
            input = Console.ReadLine();
            if (input == "exit") break;
                newchild.Properties["ou"].Add
                ("Auditing Department");
                newchild.CommitChanges();
                newchild.Close();
```

Program Synthesis

Task specification

Input/output pairs



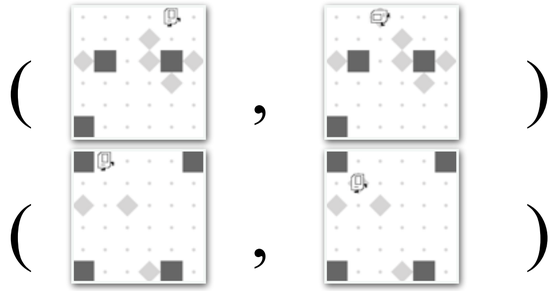
Devlin et al. “*Robustfill: Neural program learning under noisy i/o*.” ICML 2017
Balog, et al. "Deepcoder: Learning to write programs." ICLR 2017
Rudy R et al. “*Leveraging grammar and reinforcement learning for neural program synthesis*.” ICLR 2018

Program Synthesis

Task specification

Program

Input/output pairs



```
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   else:
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   move()
   turnLeft
   repeat(2):
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      putMarker()
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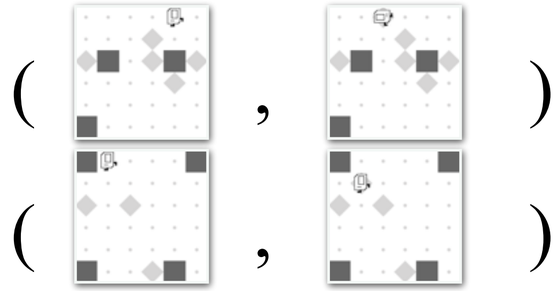
Program Synthesis

Task specification

Program

Input/output pairs



```
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   else:
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   move()
   turnLeft
   repeat(2):
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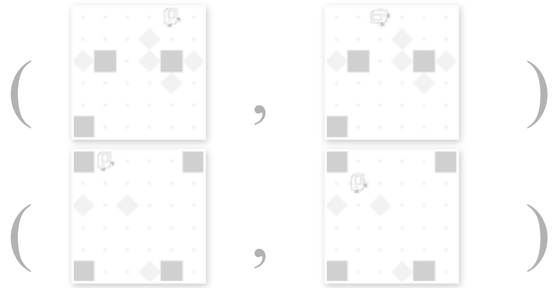
Program Synthesis

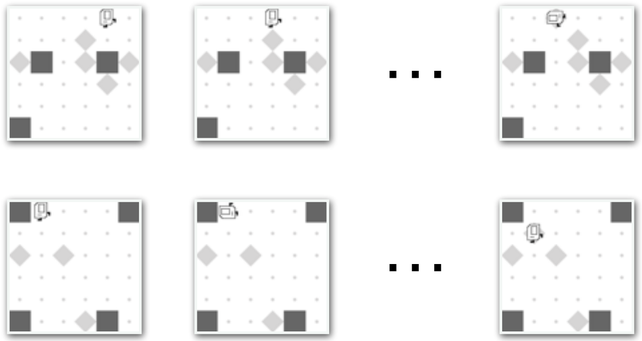
Task specification

Program

Input/output pairs



Demonstration Sequences

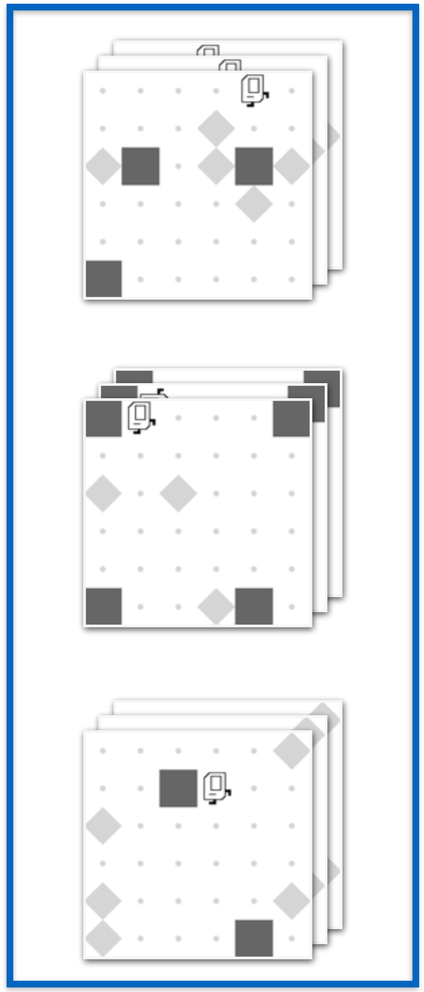


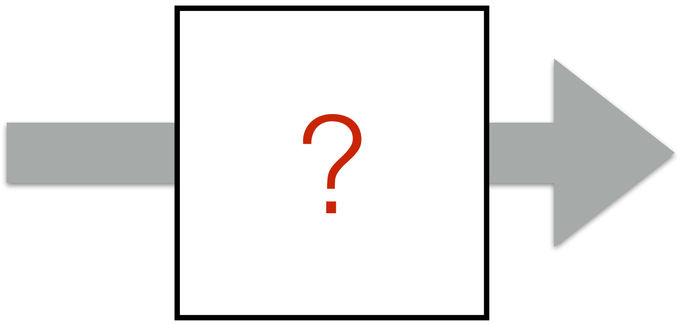
```
def run()
    if frontIsClear():
        move()
    else:
        turnLeft()
    move()
    turnLeft
    repeat(2):
        turnRight()
        putMarker()
```

Problem Formulation

Input

a set of demo videos

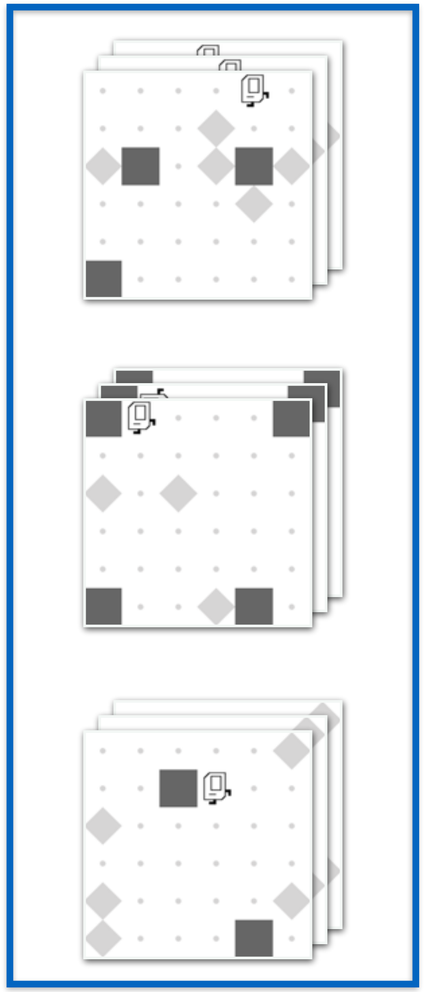


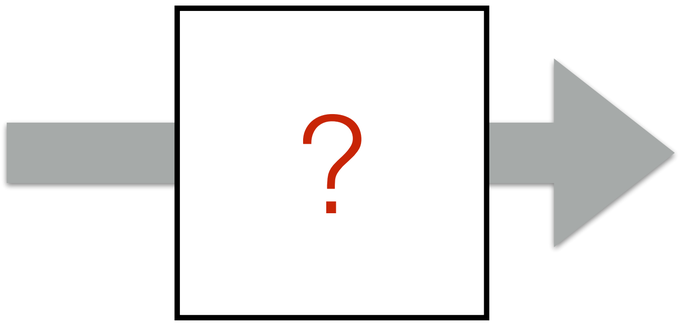


Problem Formulation

Input

a set of demo videos



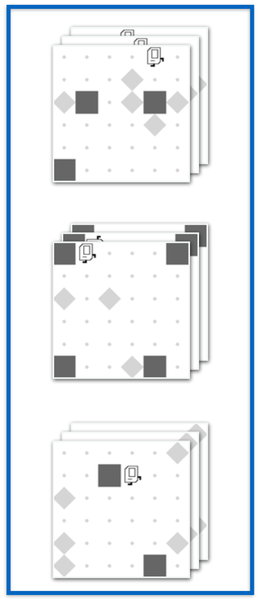


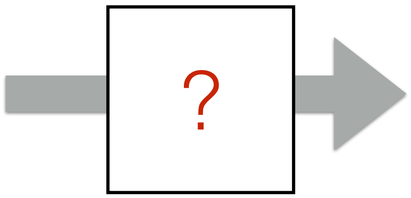
Output

a program describing the demonstrated behavior

Problem Formulation

Input
a set of demo videos





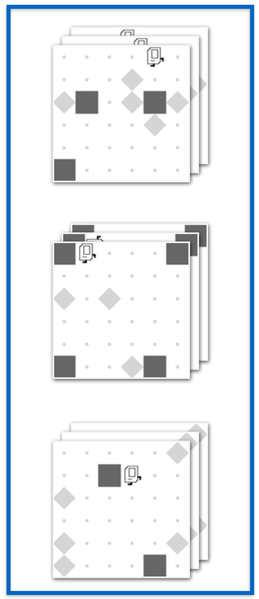
Output
a program describing the demonstrated behavior

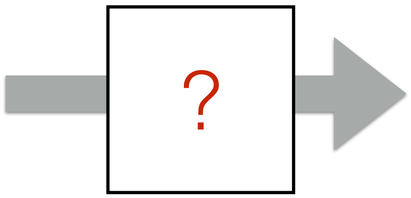
Challenges

- **Extracting unique behaviors** in each demo
- **Summarizing** diverse behaviors as a program

Problem Formulation

Input
a set of demo videos





Output
a program describing the demonstrated behavior

Challenges

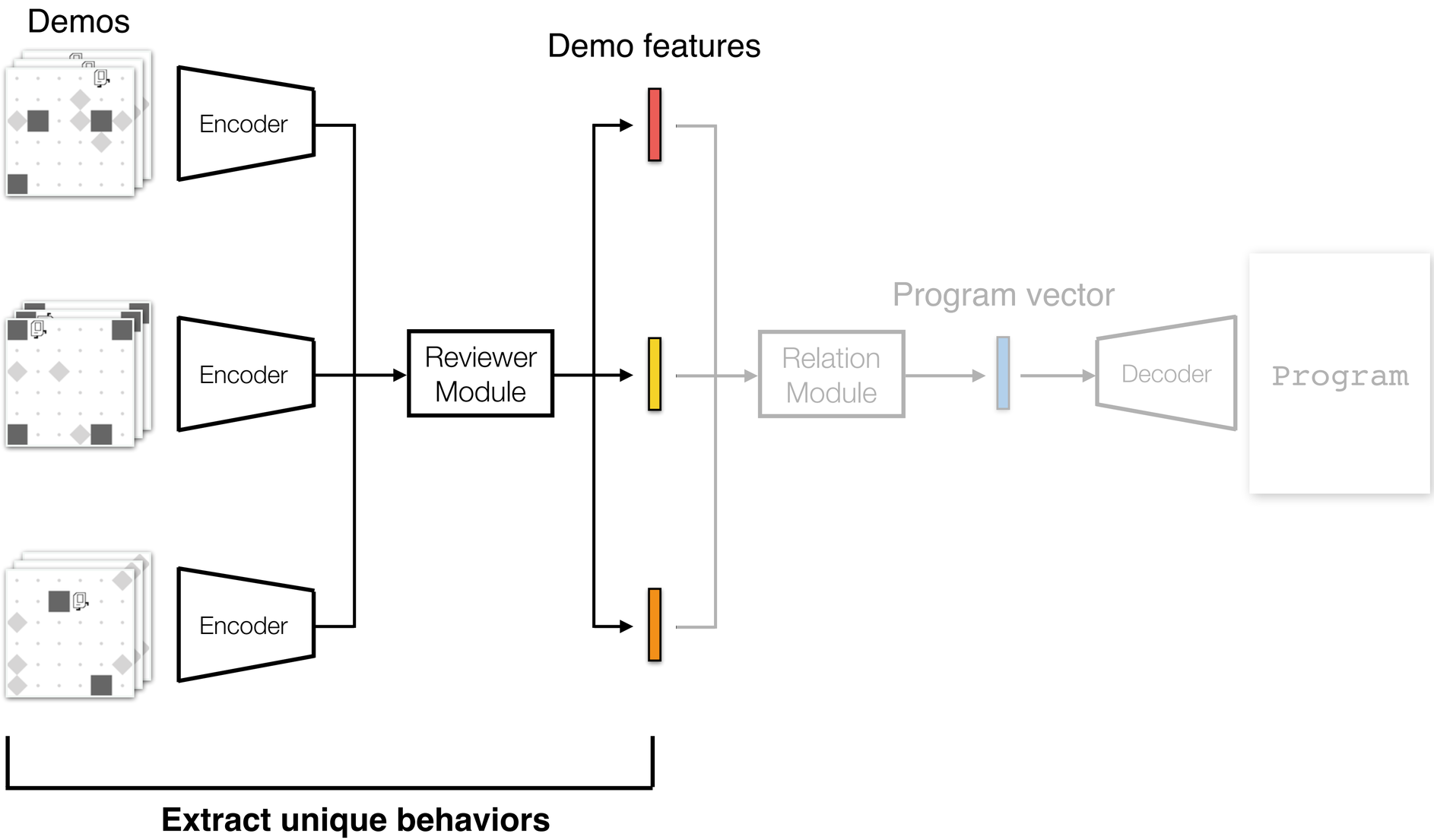
- **Extracting unique behaviors** in each demo

  Reviewer module

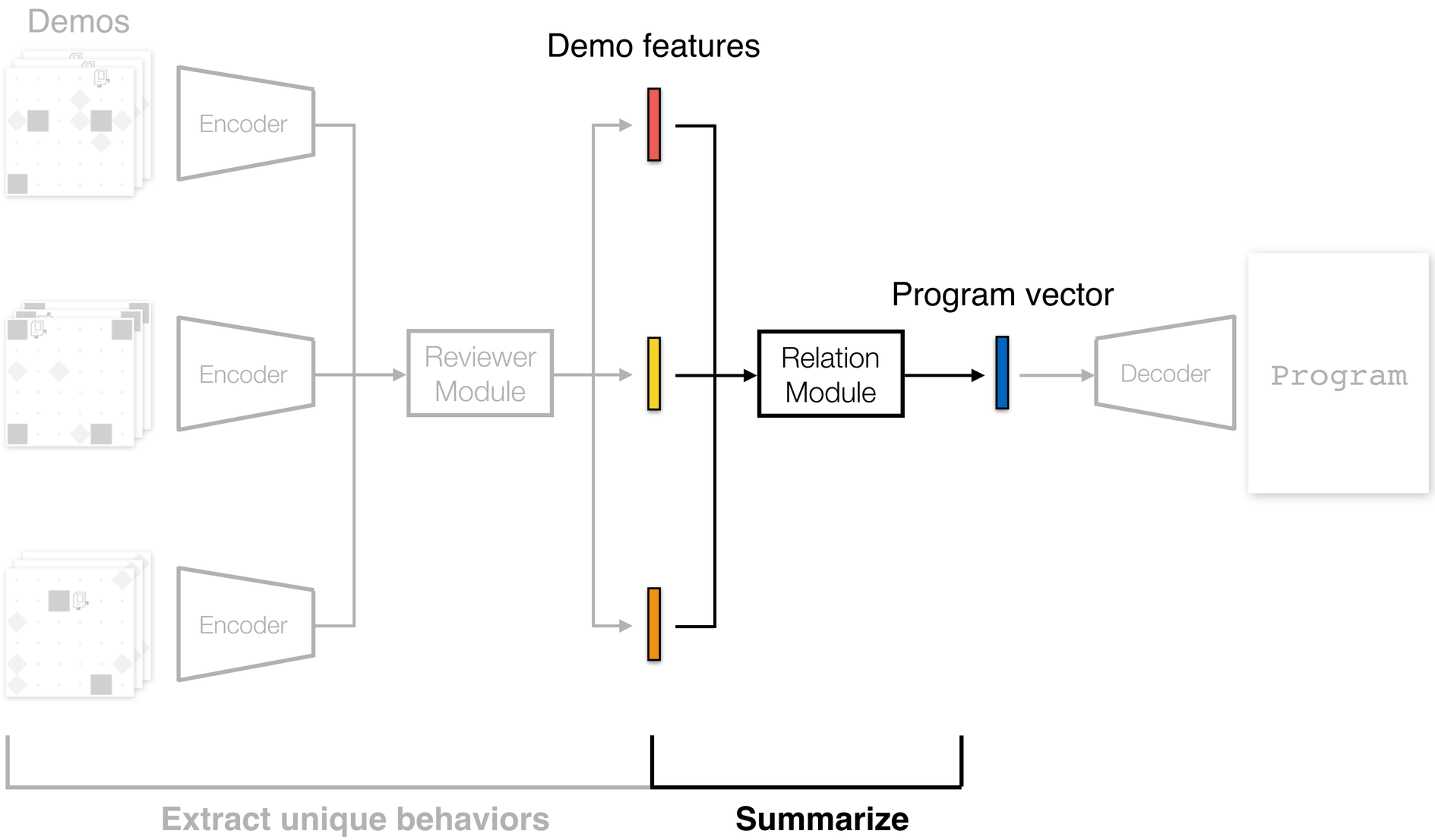
- **Summarizing** diverse behaviors as a program

  Relation module

Model Overview



Model Overview



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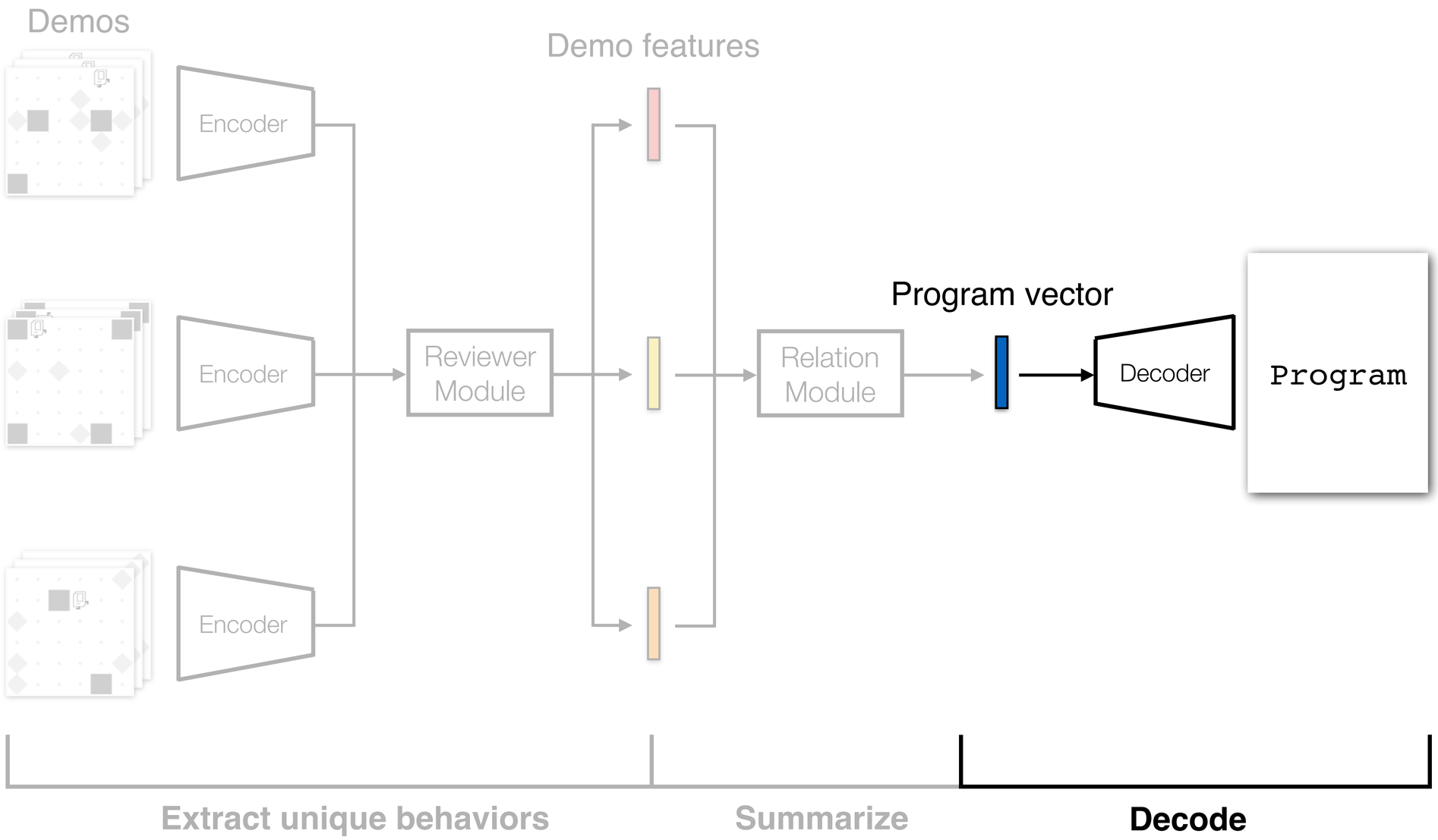

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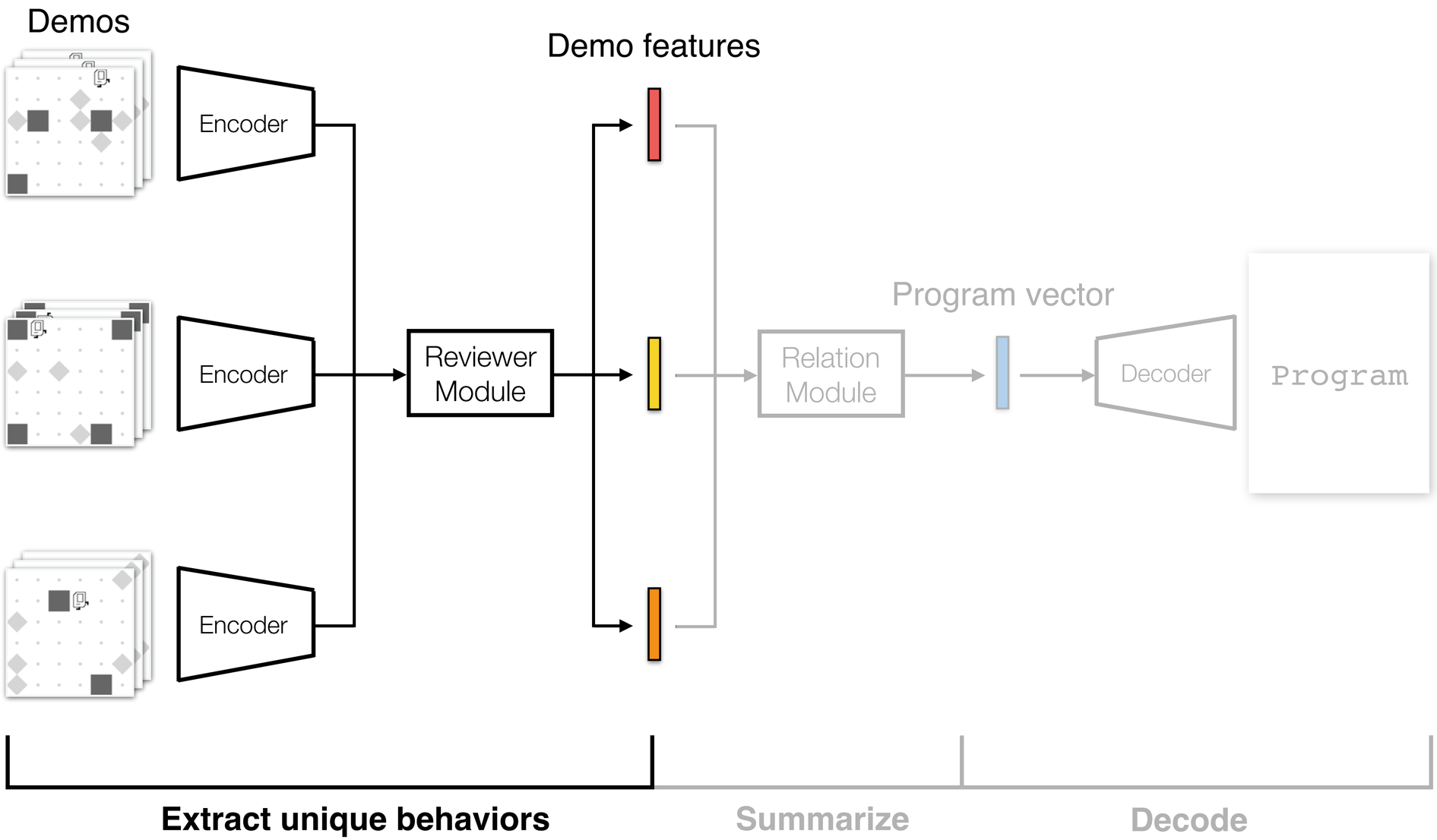
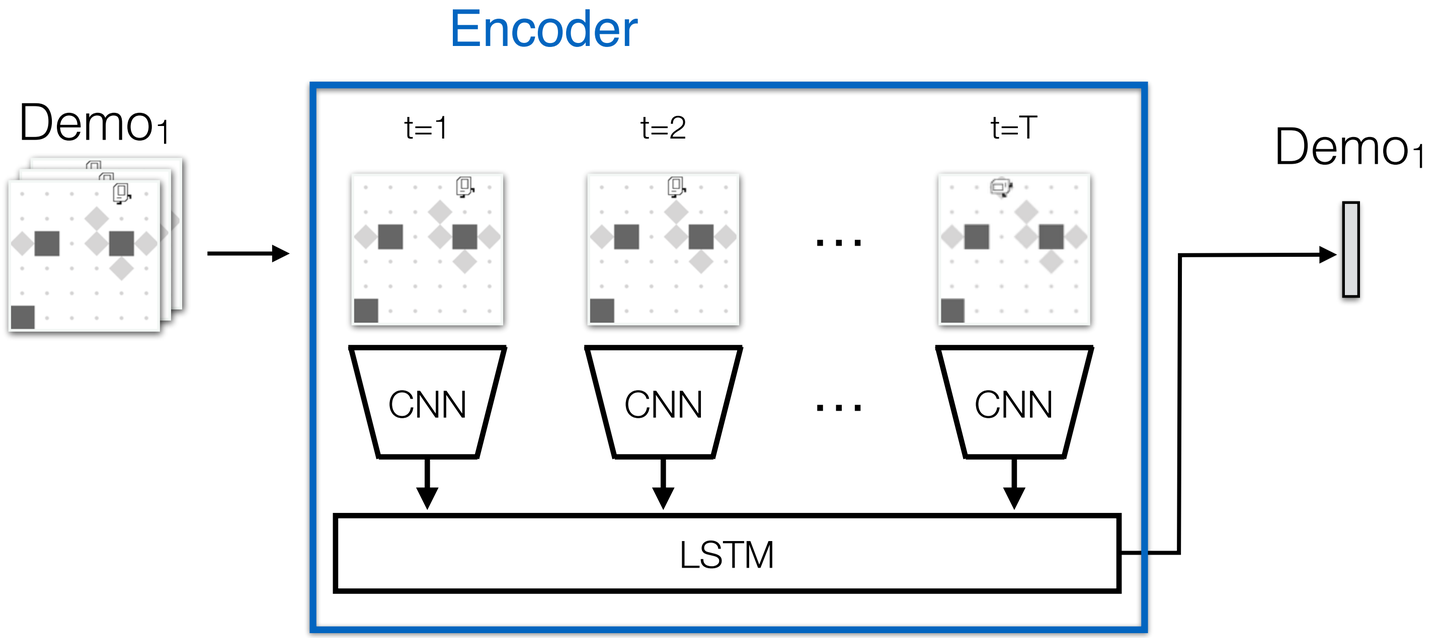
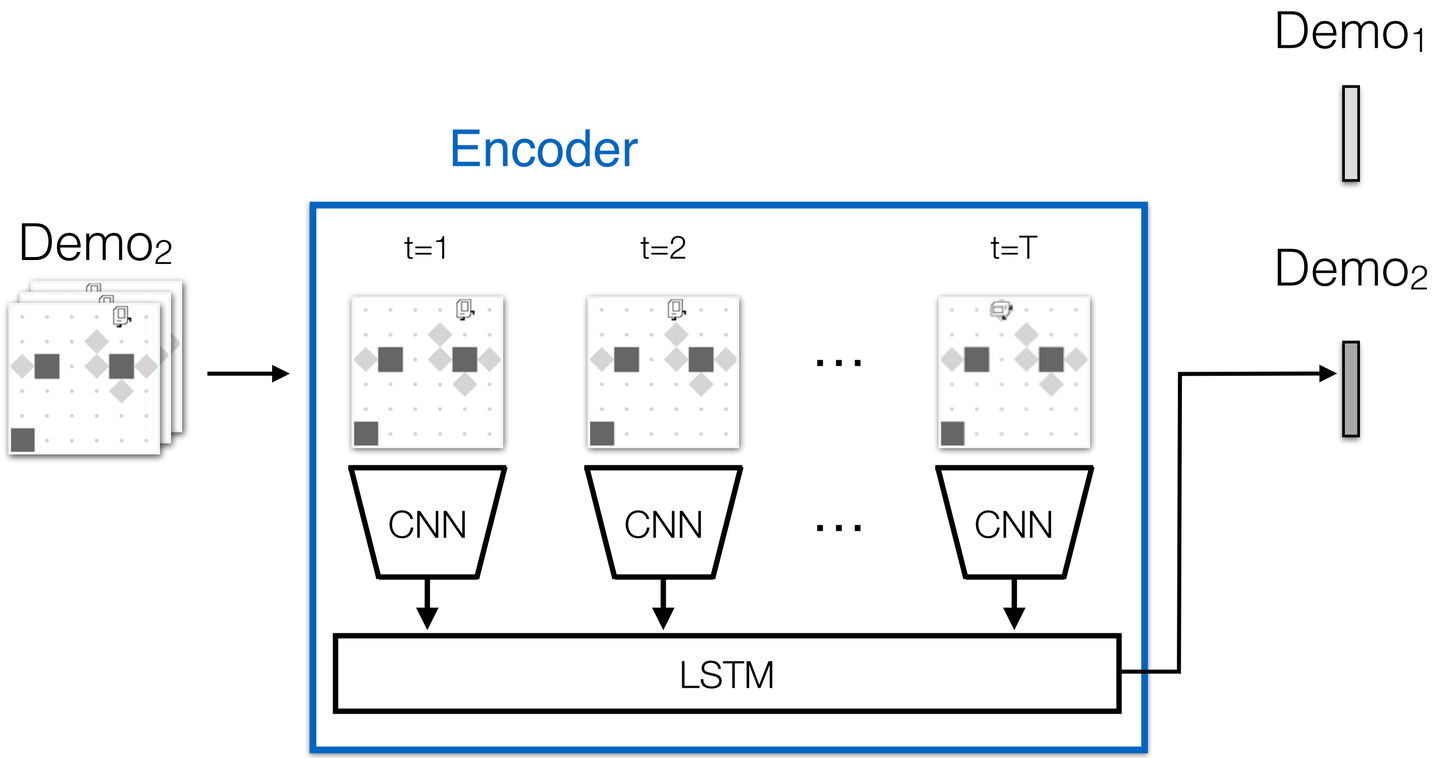


Reviewer Module



Reviewer Module



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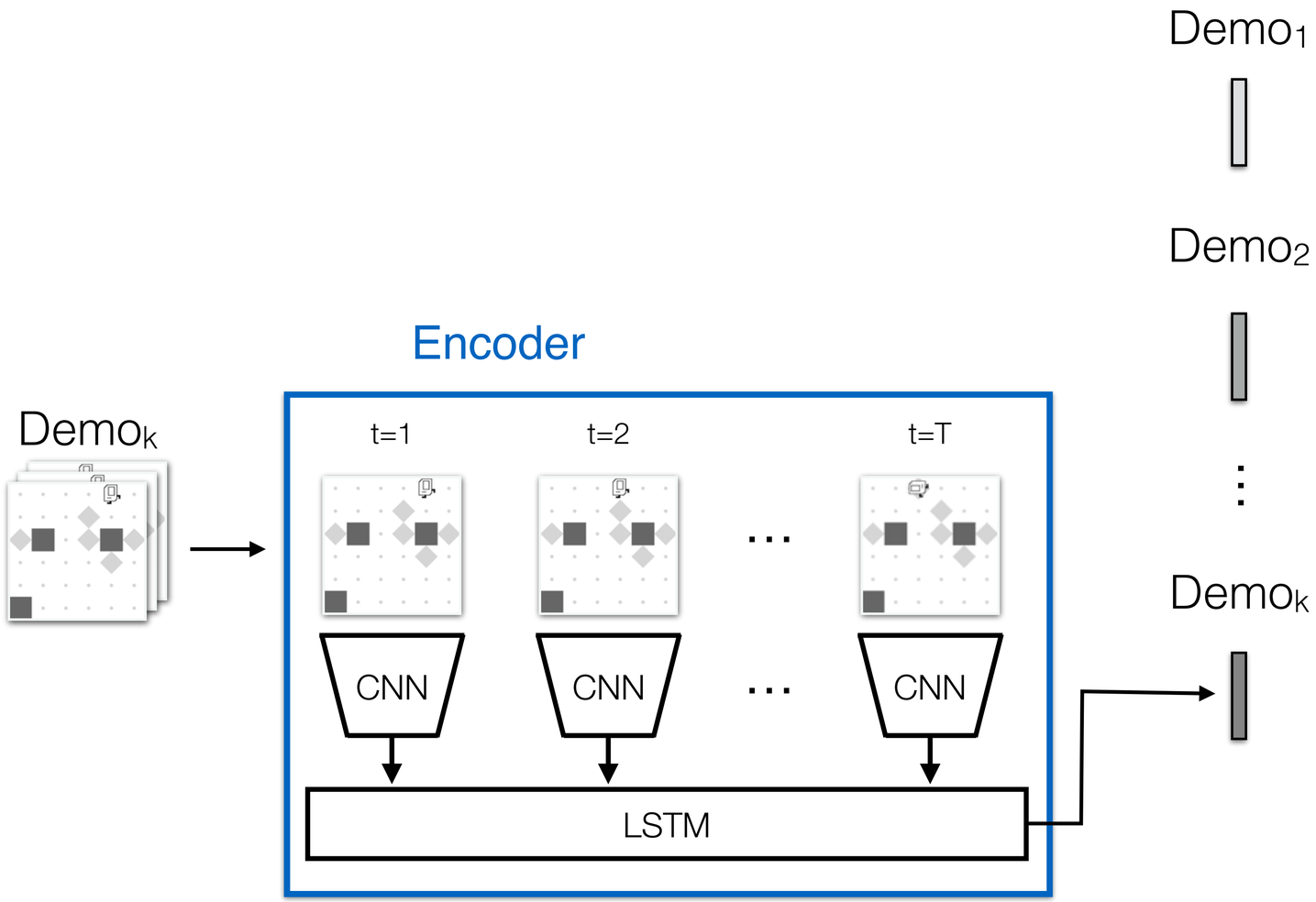

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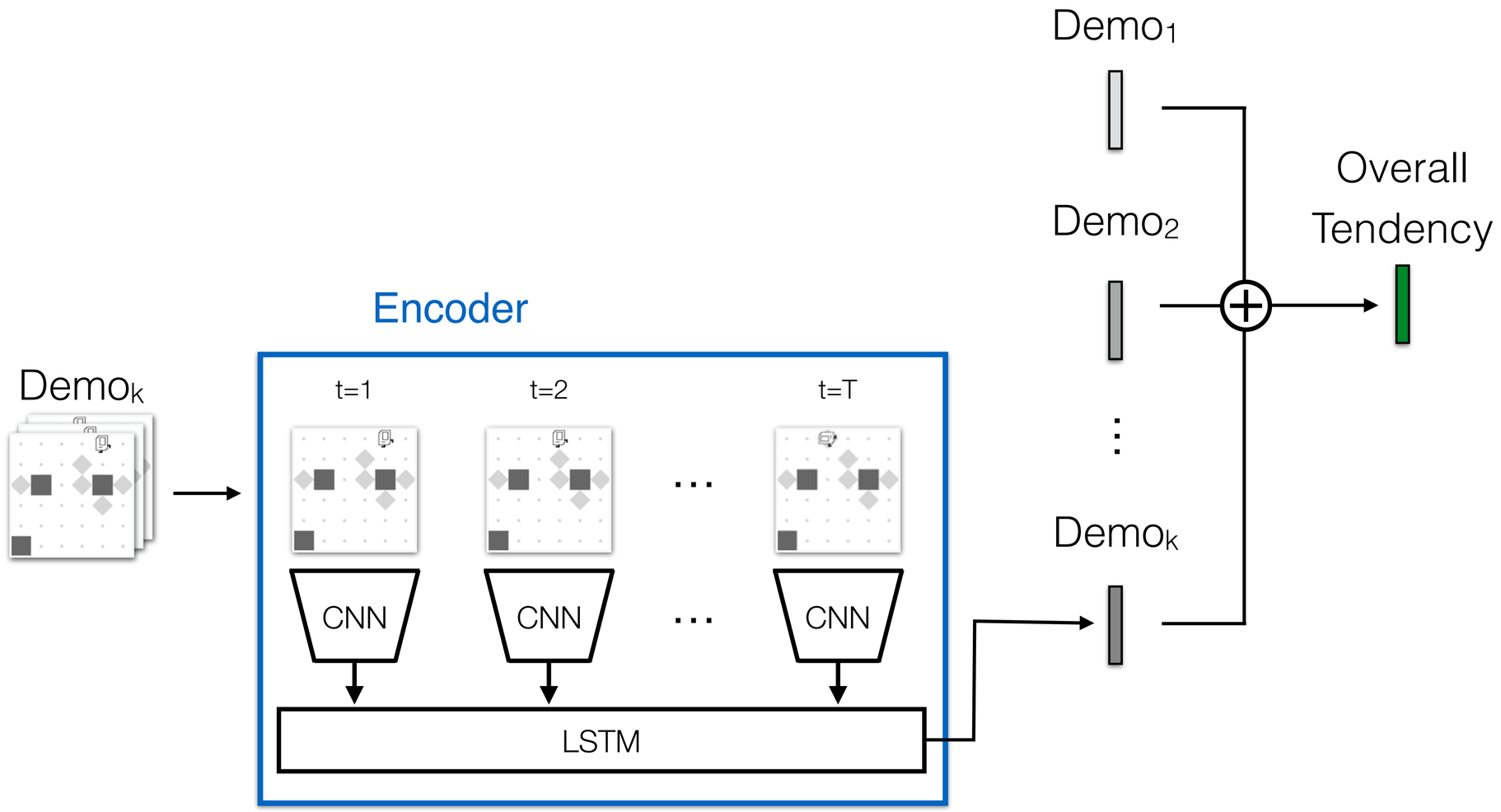

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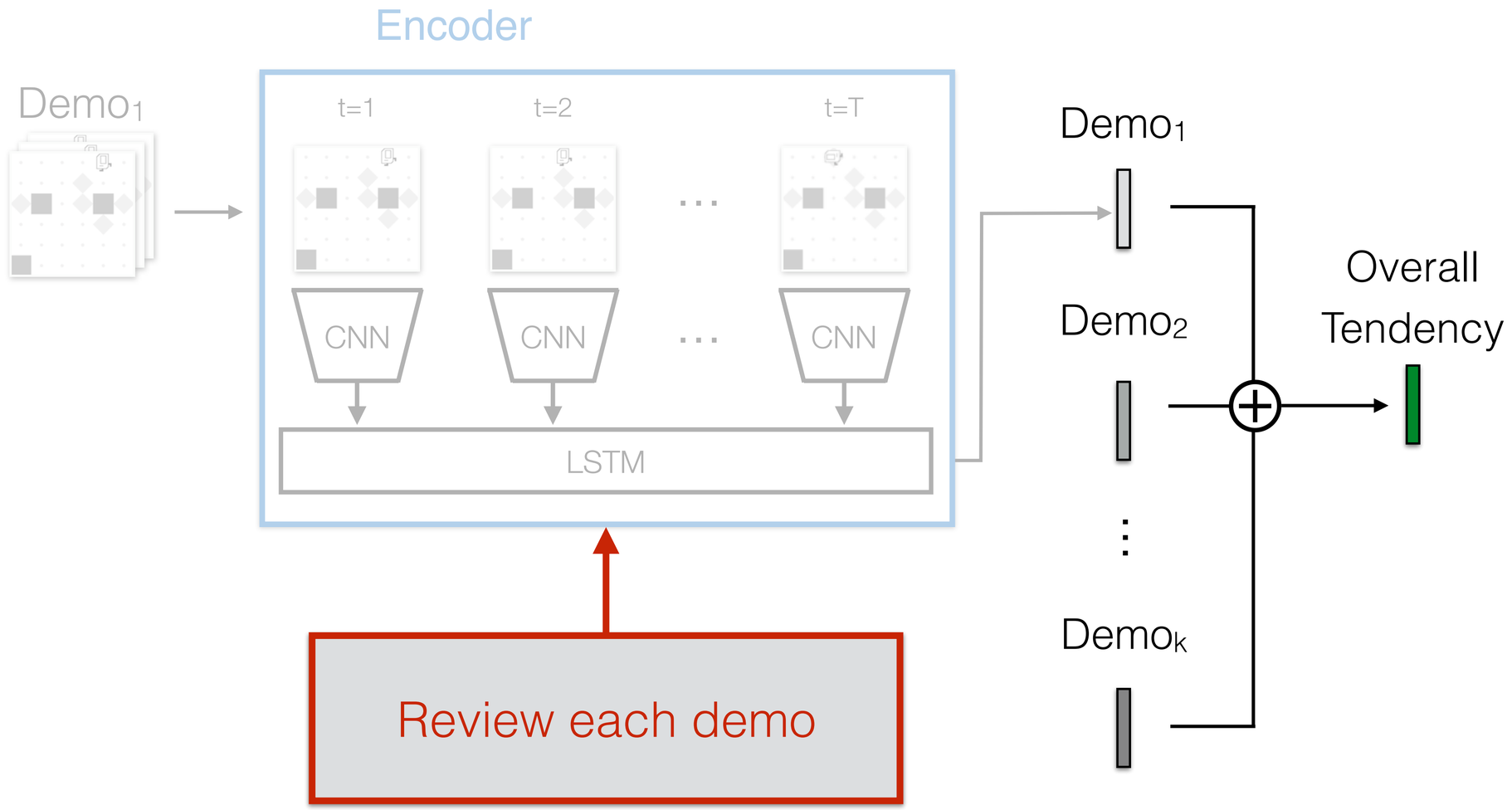

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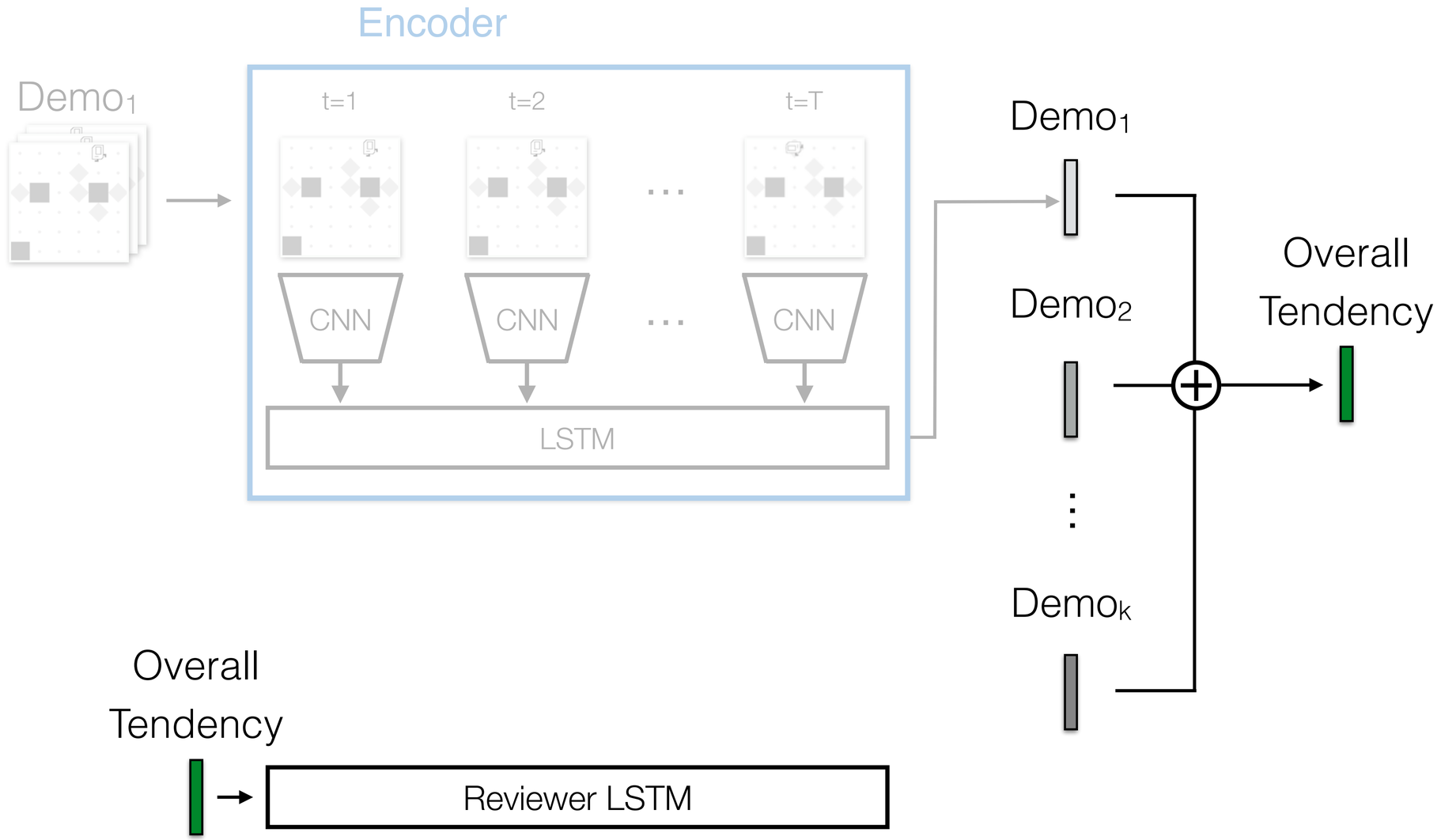

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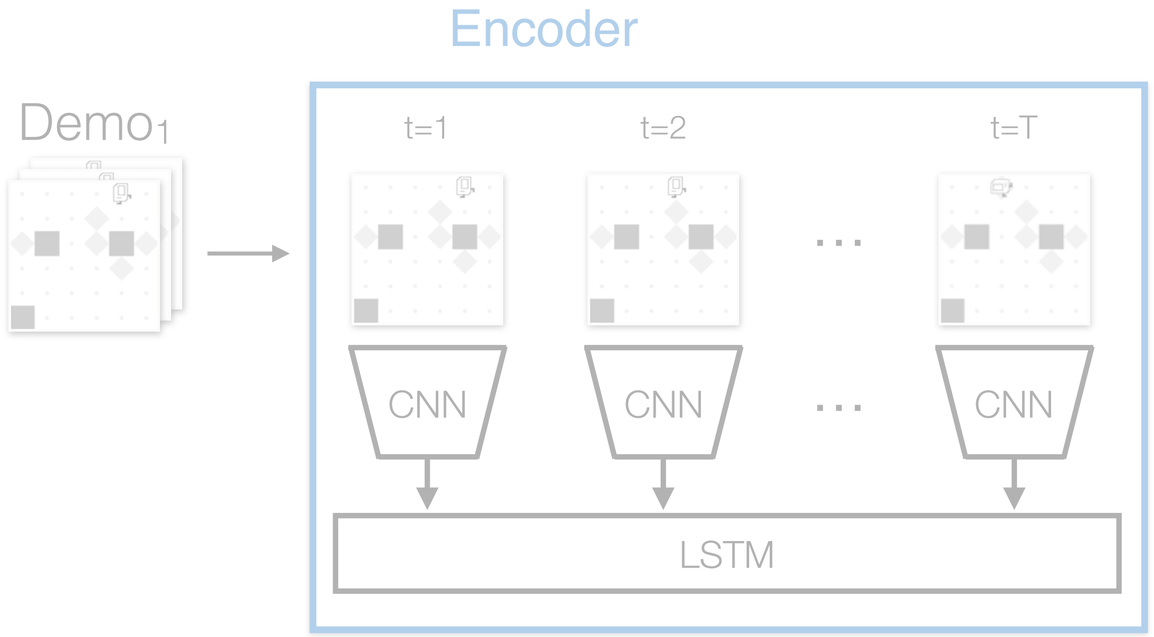
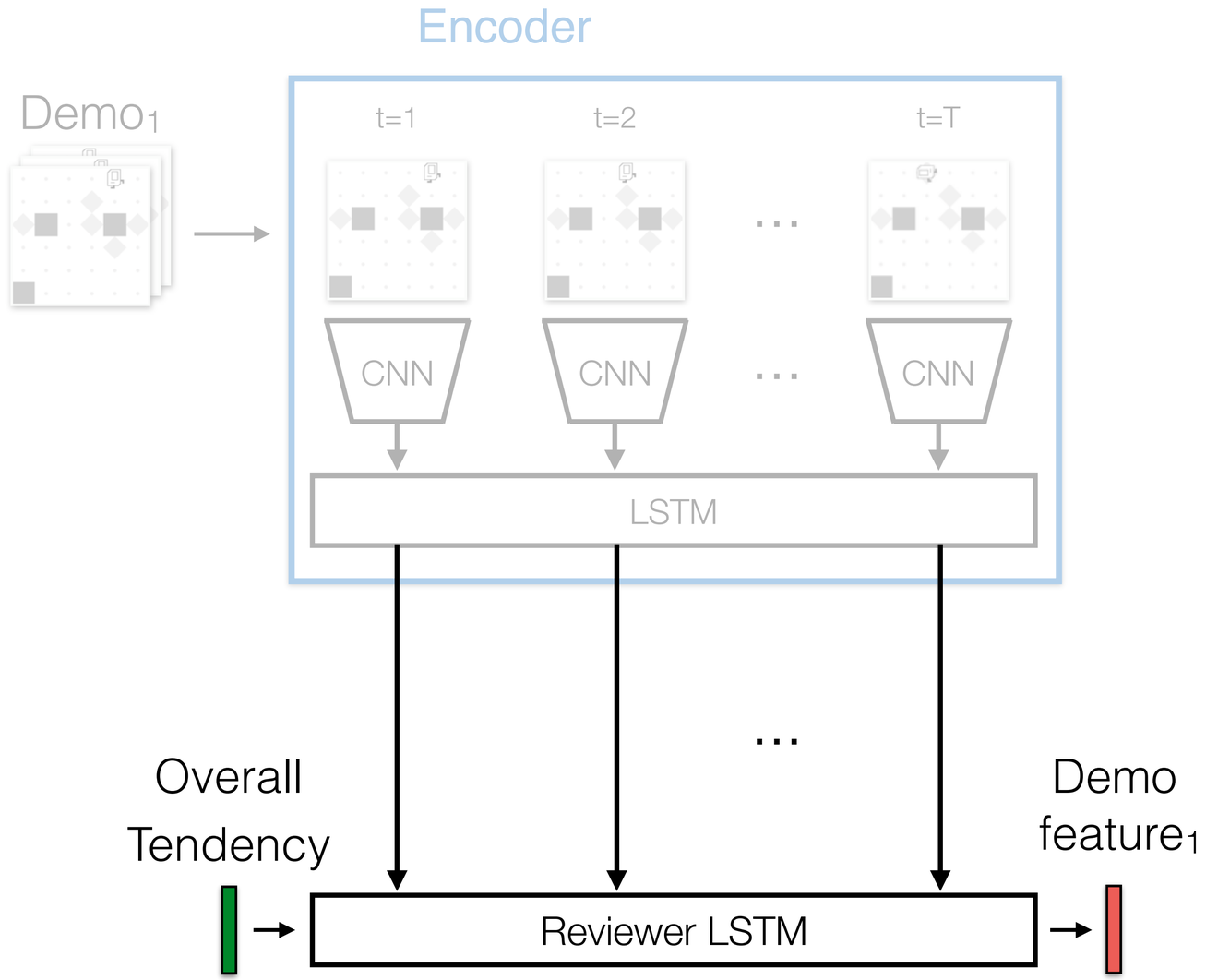
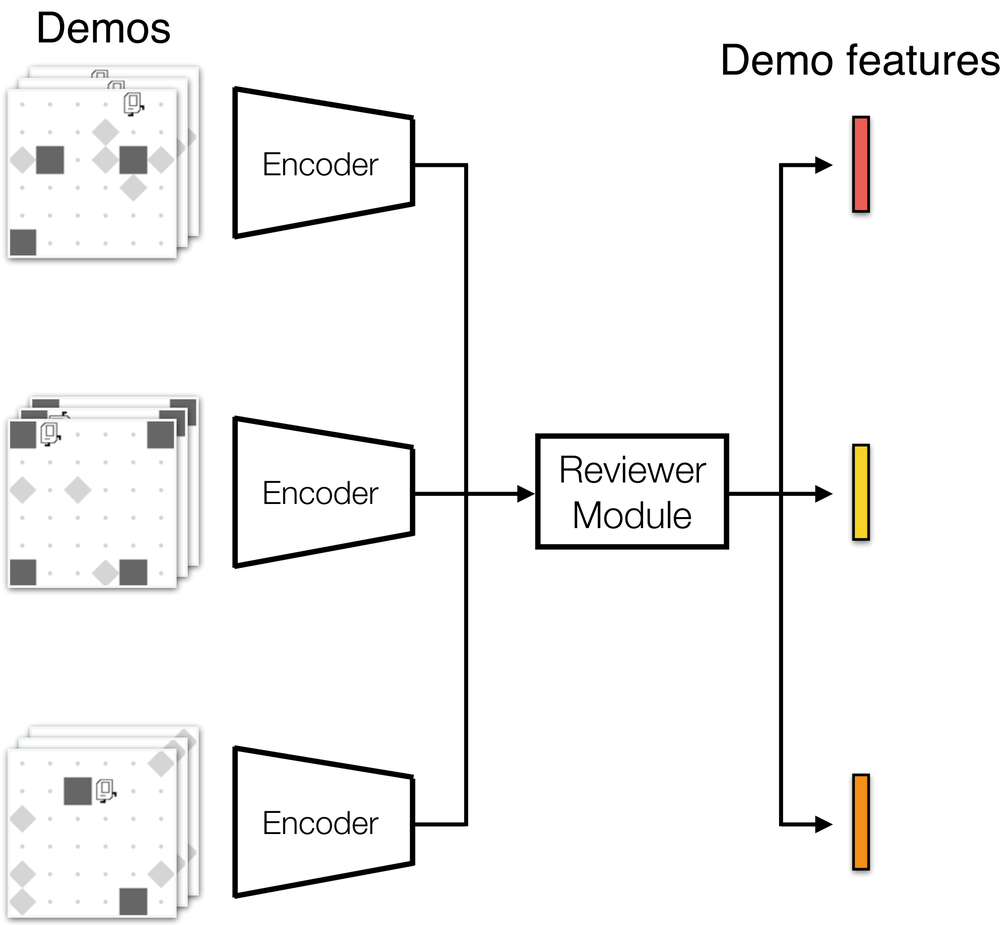


Overall Tendency

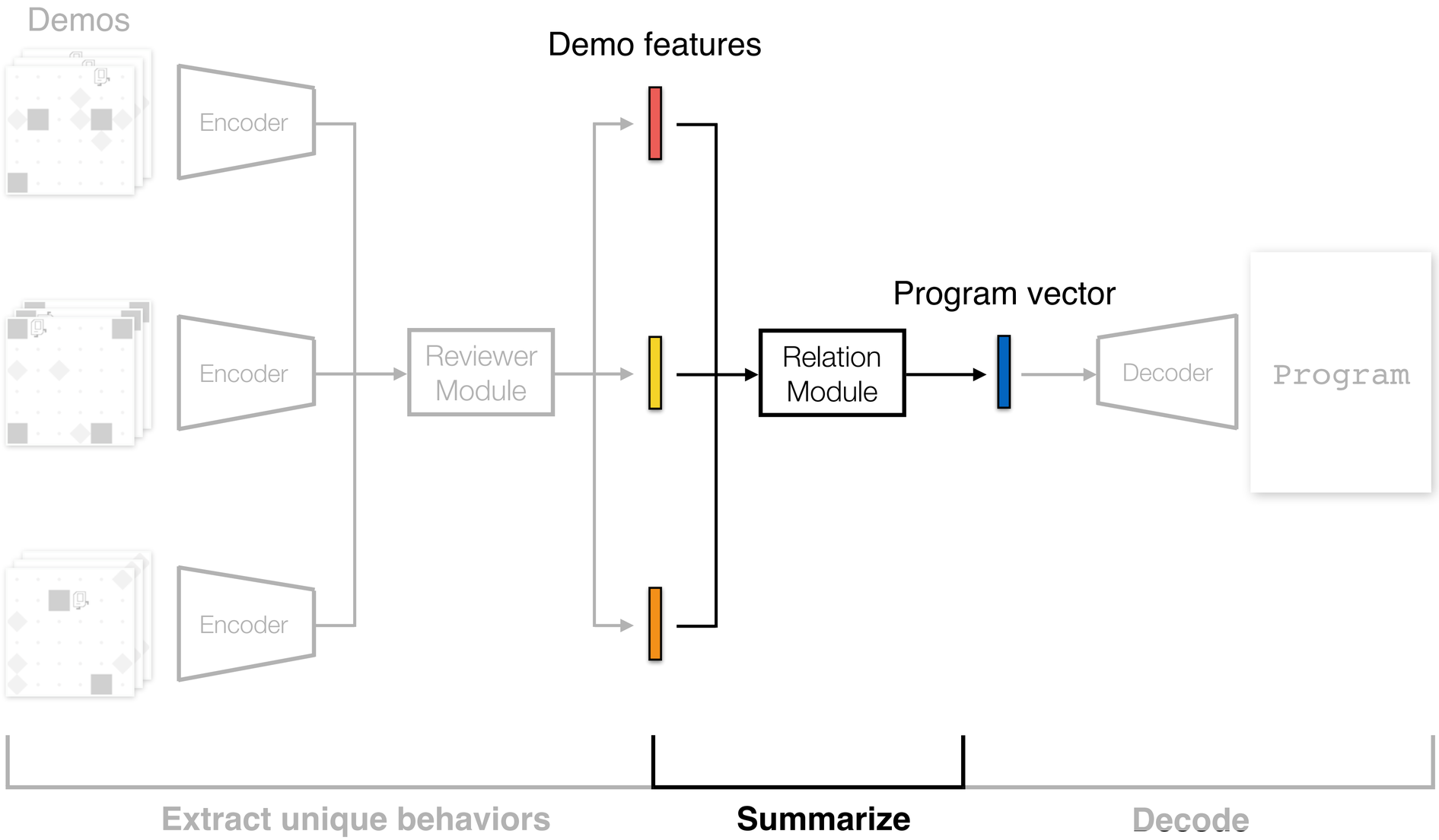
Reviewer Module



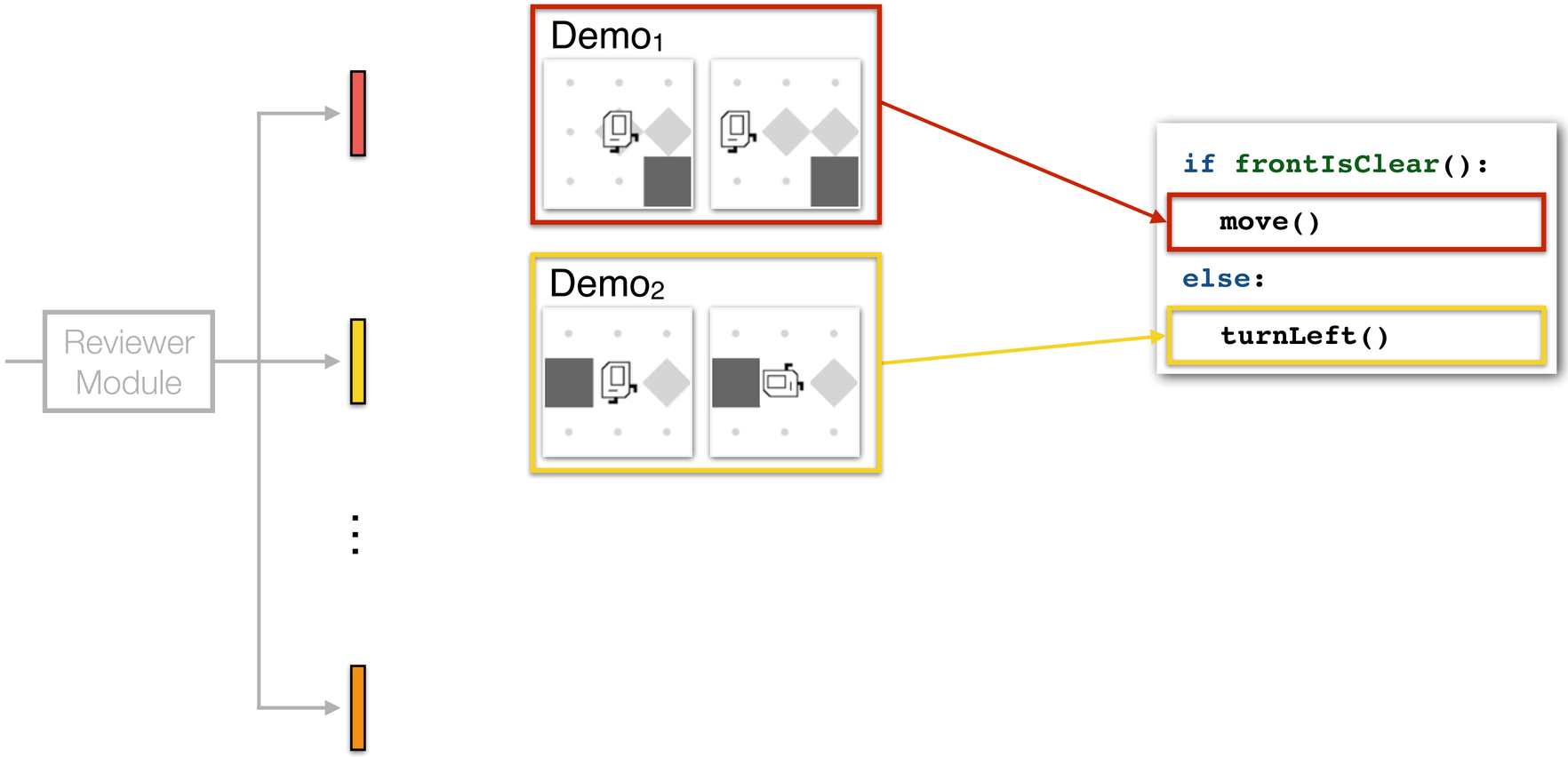
Model Overview



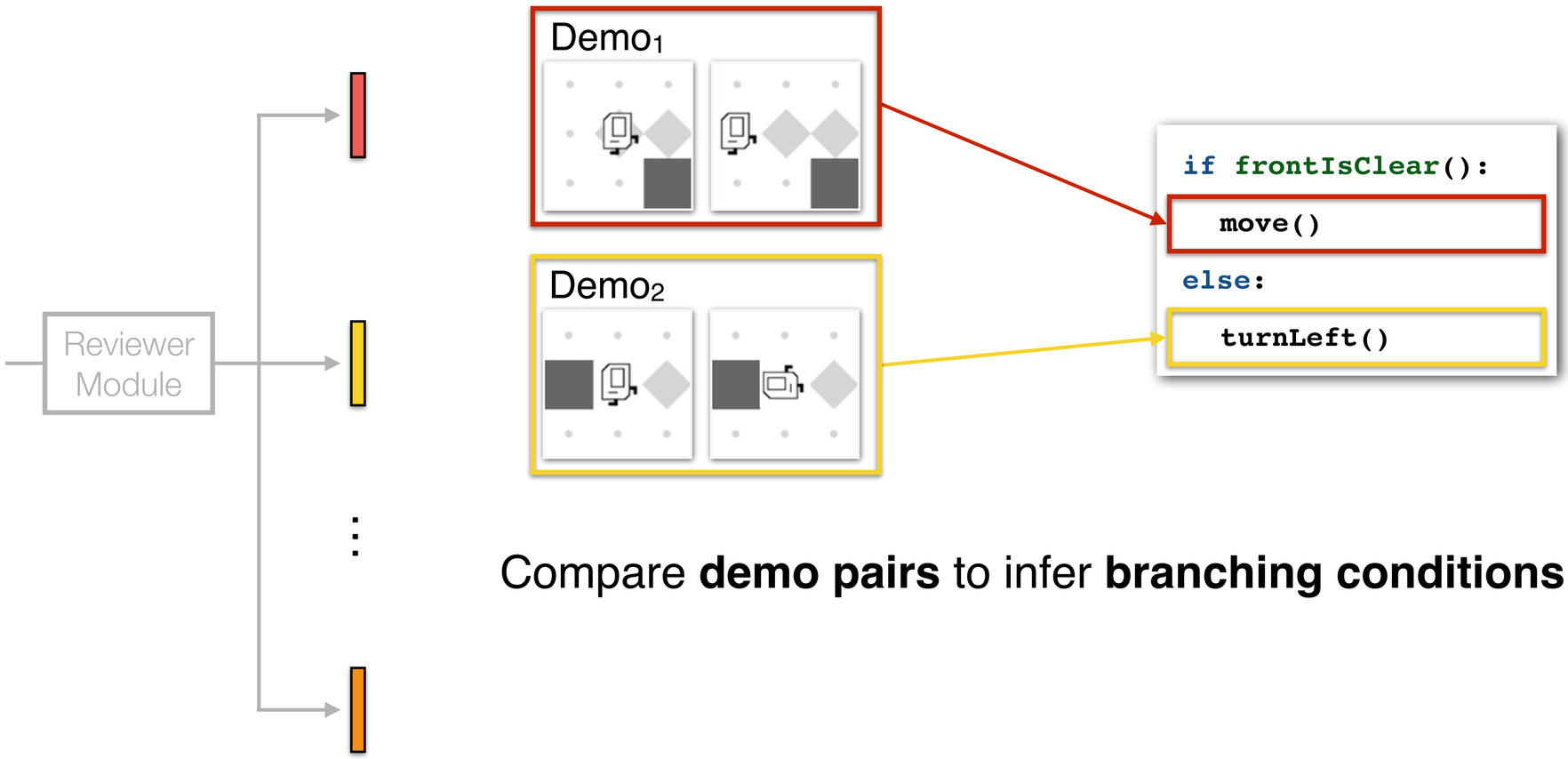
Model Overview



Relation Module

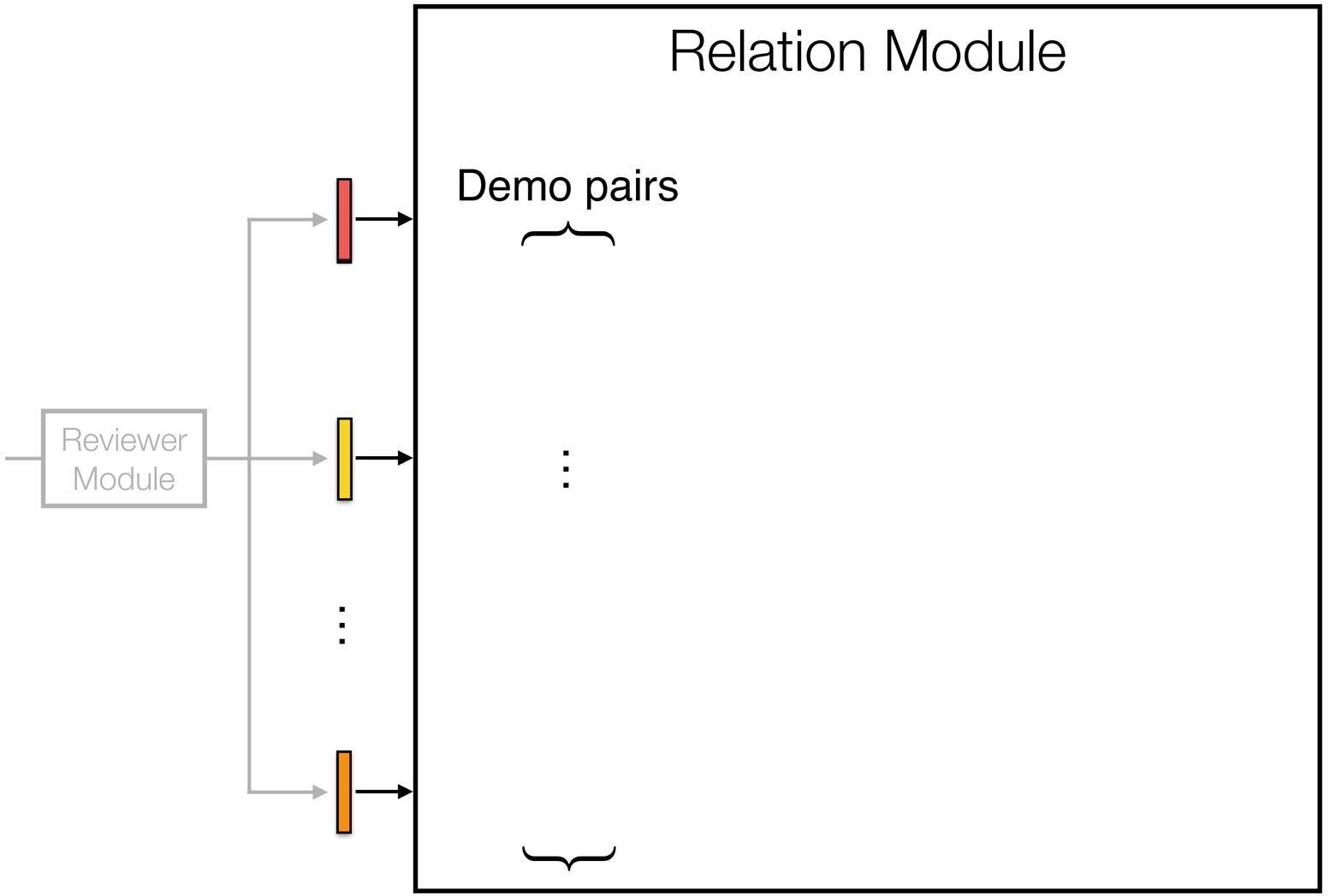


Relation Module



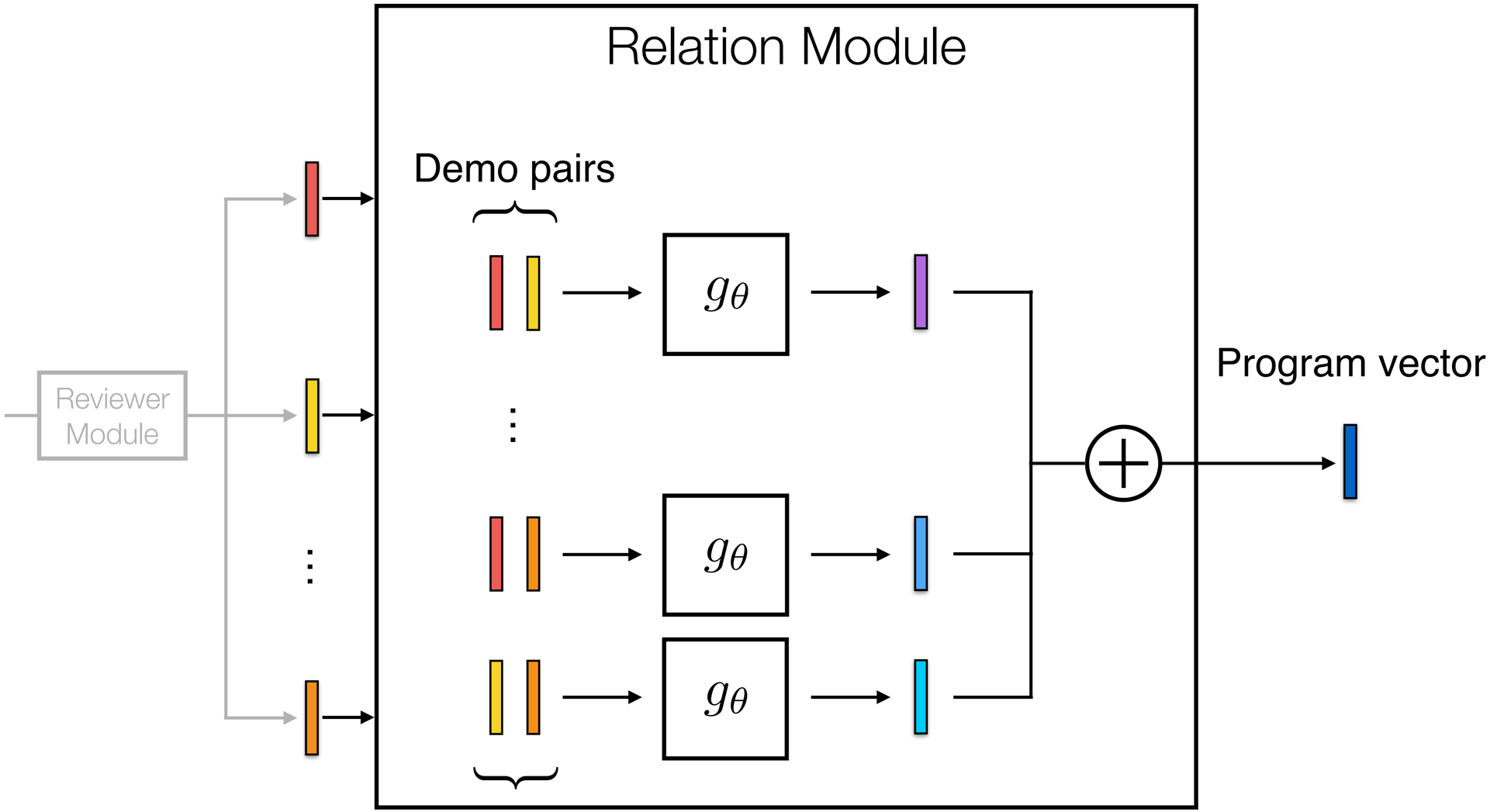
Compare **demo pairs** to infer **branching conditions**

Relation Module



Santoro et al. "A simple neural network module for relational reasoning." NIPS 2017

Relation Module



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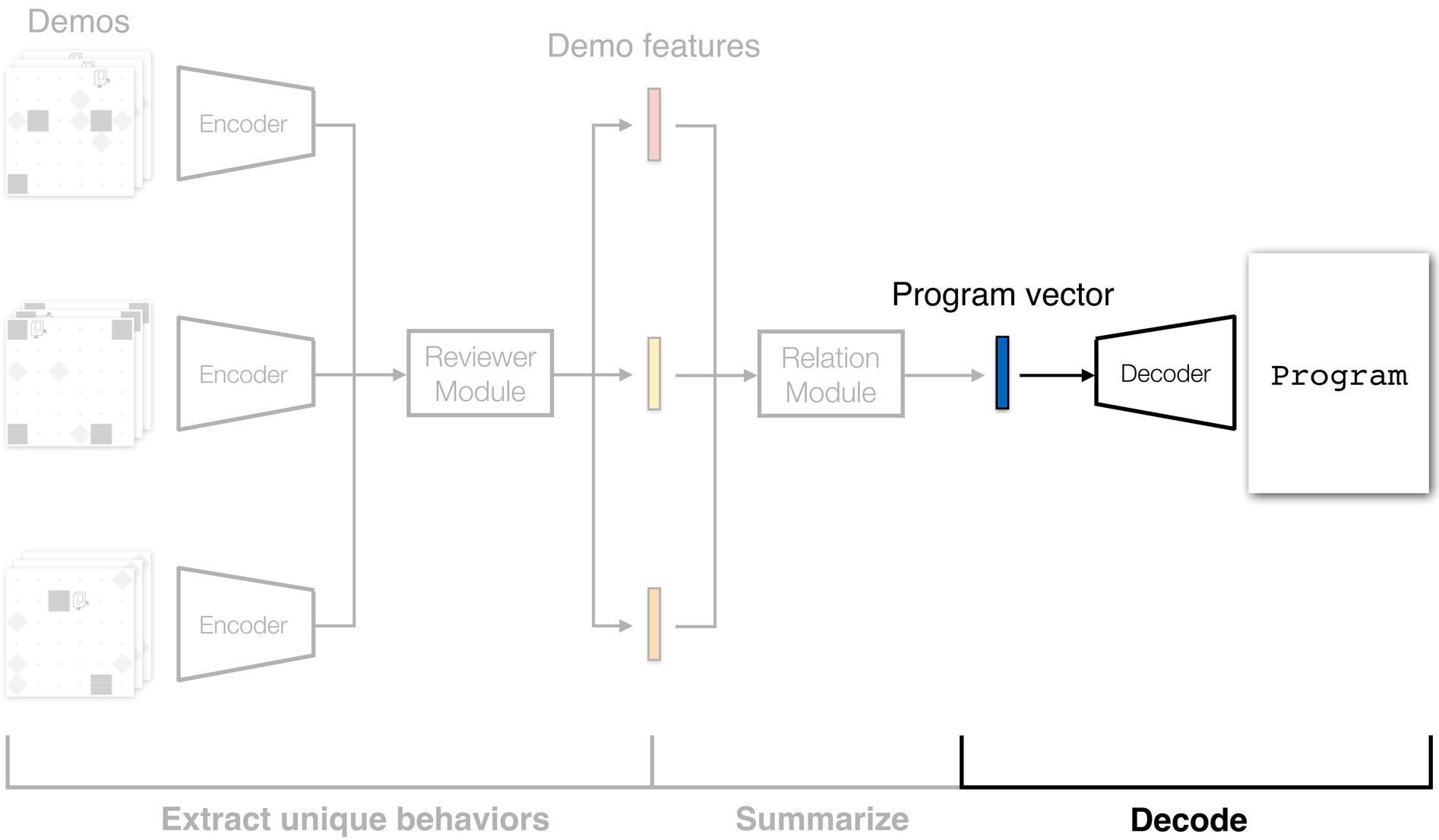
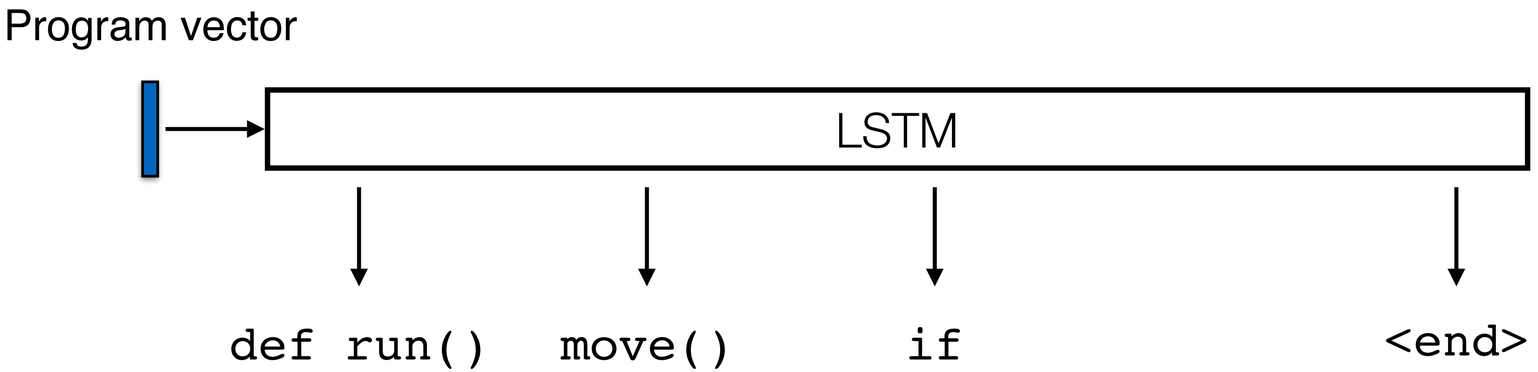


Decode a Program



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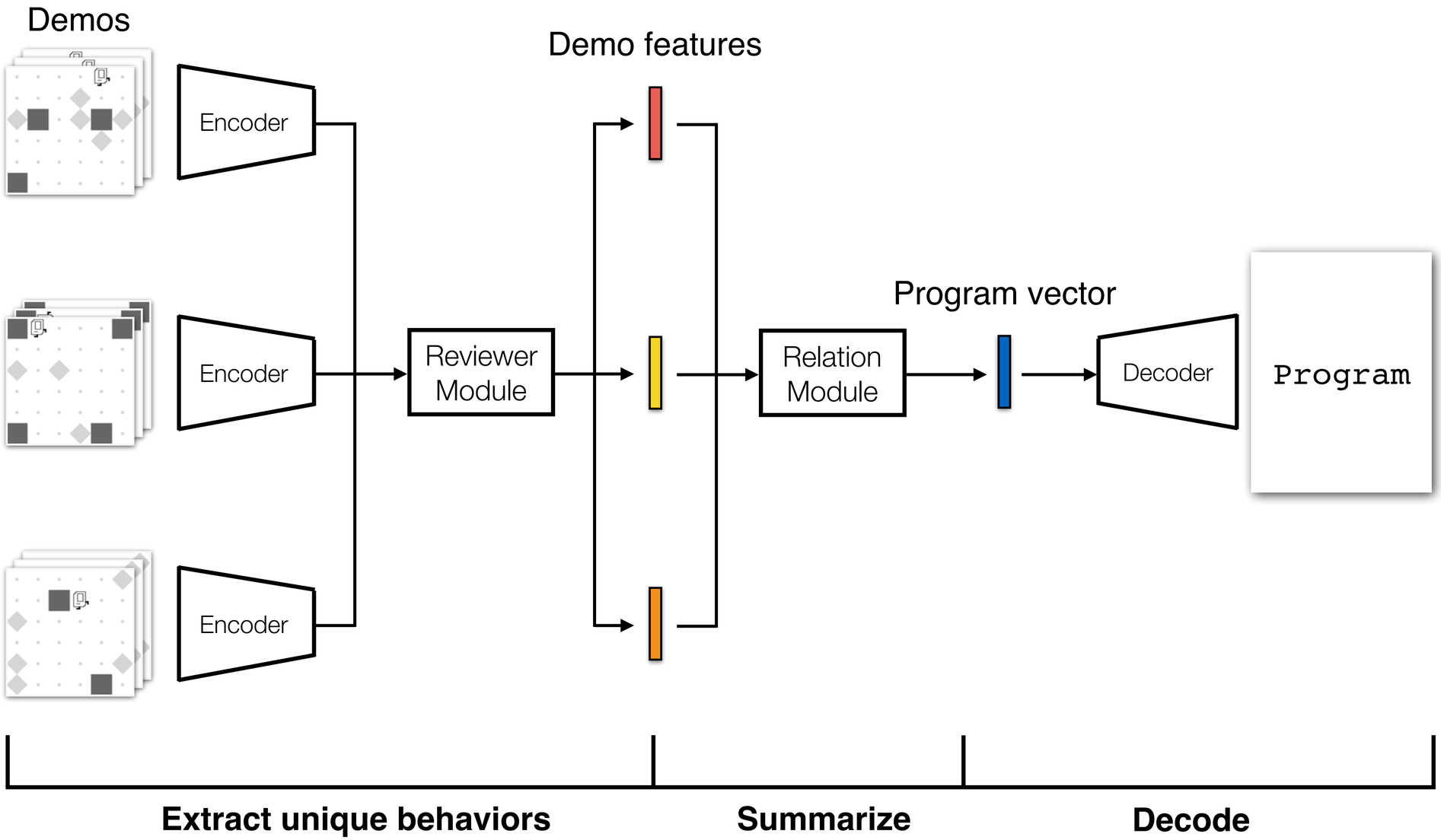
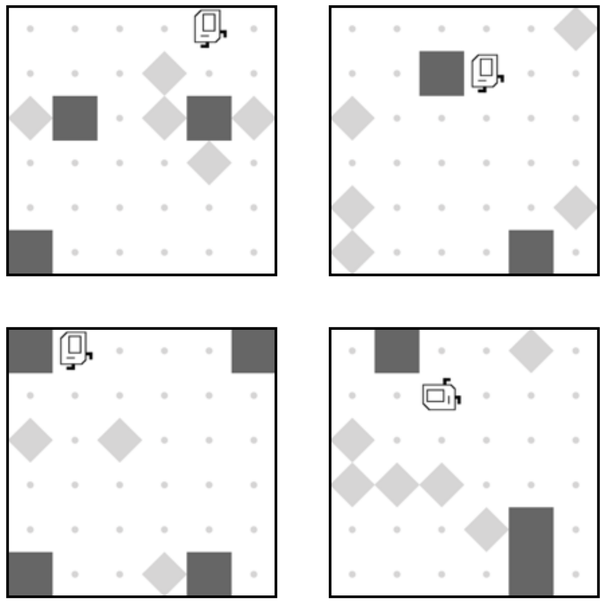


Experiments

Environments

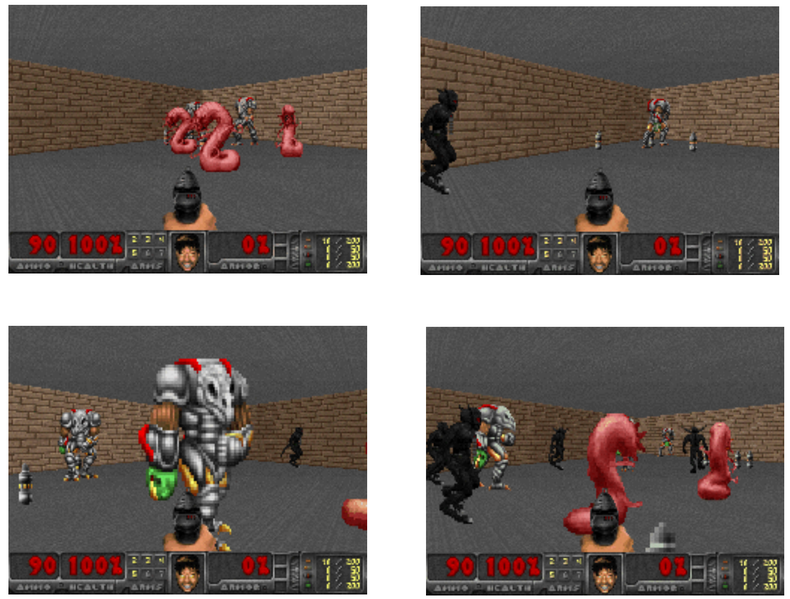
Karel

```
def run()
    if frontIsClear():
        move()
    else:
        turnLeft()
    move()
    turnLeft
    repeat(2):
        turnRight()
        putMarker()
```



ViZDoom

```
def run()
    while(inTarget(
            HellKnight)):
        attack()
        moveForward()
    if isThere(Demon):
        moveRight()
    else:
        moveLeft()
        moveBackward()
```

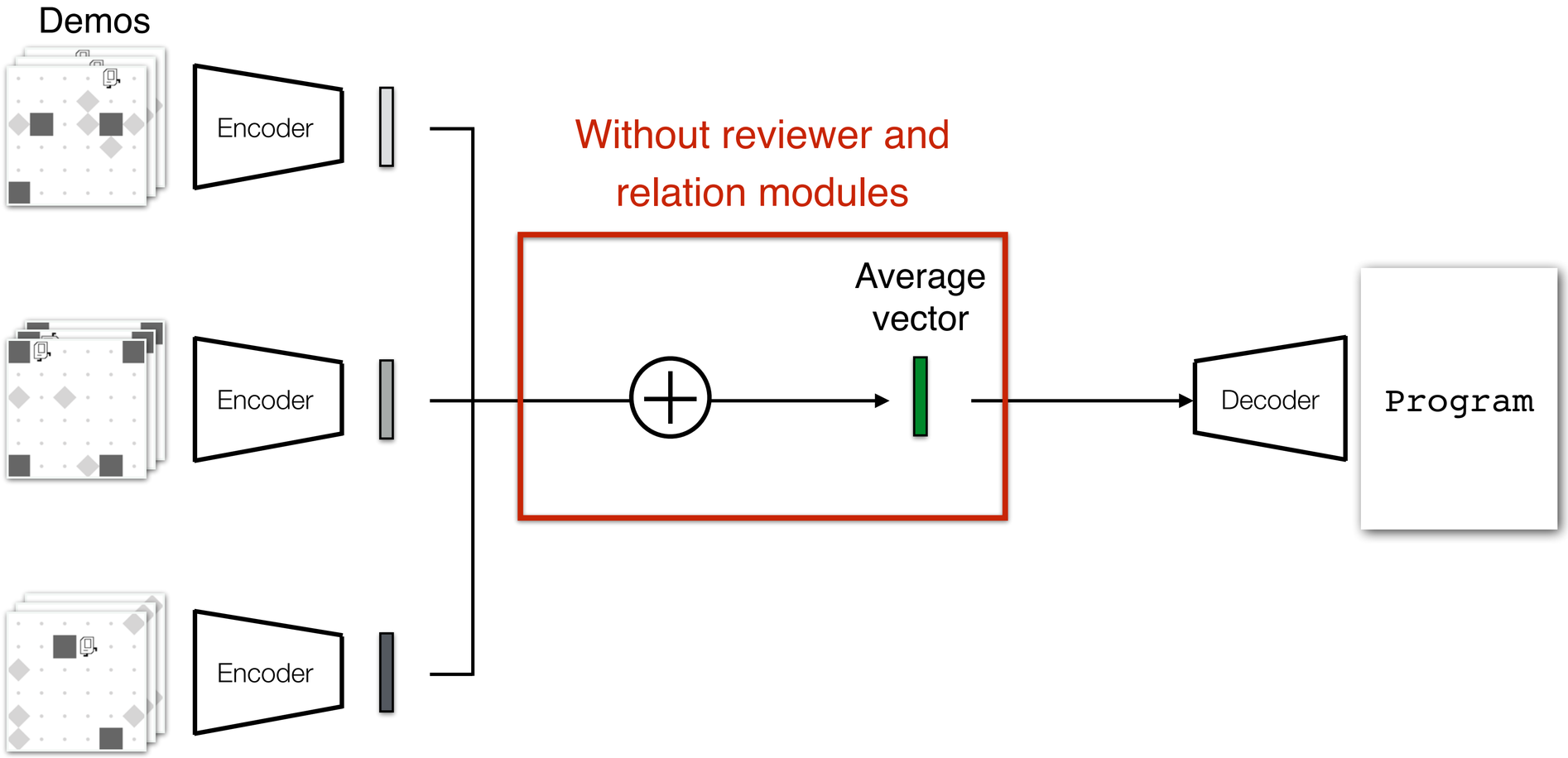


Richard E Pattis. “Karel the robot: a gentle introduction to the art of programming.” John Wiley & Sons, Inc., 1981

Kempka et al., “Vizdoom: A doom-based ai research platform for visual reinforcement learning.” In CIG, 2016

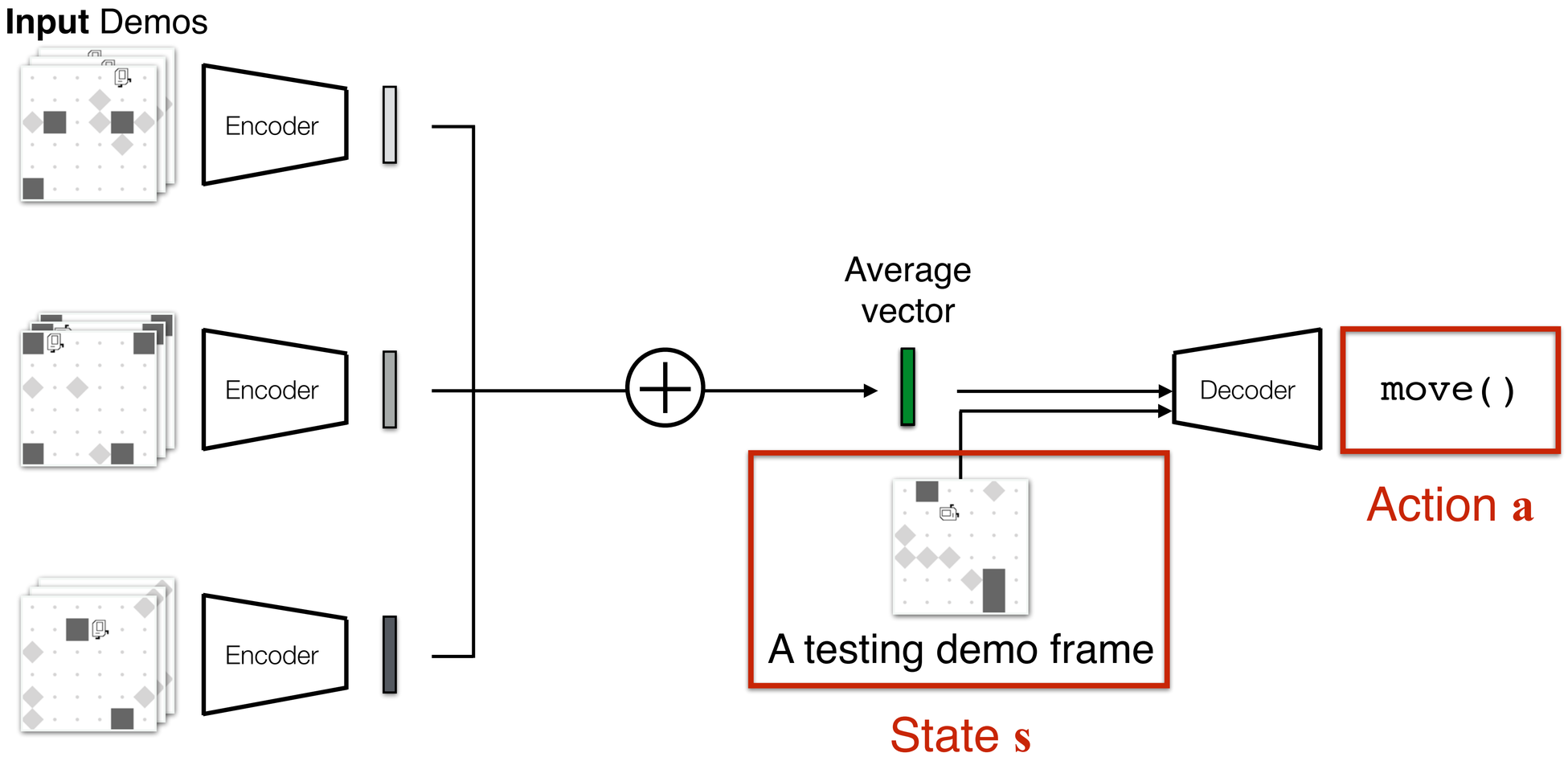
Baselines

- Program **synthesis** baseline
- Program **induction** baseline



Baselines

- Program **synthesis** baseline
- Program **induction** baseline



Example Result: Karel

Ground truth

```
def run():
    if frontIsClear():
        move()
    else:
        turnLeft()
    move()
    repeat(2):
        turnRight()
        putMarker()
```

Synthesis baseline

```
def run():
    move()
    move()
    turnRight()
    putMarker()
    turnRight()
    putMarker()
```

Miss the if-else statement

Example Result: Karel

Ground truth

```
def run():
    if frontIsClear():
        move()
    else:
        turnLeft()
    move()
    repeat(2):
        turnRight()
        putMarker()
```

Synthesis baseline

```
def run():
    move()
    move()
    turnRight()
    putMarker()
    turnRight()
    putMarker()
```

Ours

```
def run():
    if frontIsClear():
        move()
    else:
        turnLeft()
    move()
    turnRight()
    putMarker()
    turnRight()
    putMarker()
```

Example Result: ViZDoom

Ground truth

```
def run():
  if inTarget(Demon):
    attack()
    moveLeft()
  else:
    moveRight()
  if isThere(Demon):
    attack()
  moveLeft()
```

Synthesis baseline

```
def run():
  while(inTarget(
      HellKnight)):
    attack()
  if isThere(Demon):
    moveRight()
    attack()
  else:
    moveLeft()
```

Example Result: ViZDoom

Ground truth

```
def run():
  if inTarget(Demon):
    attack()
    moveLeft()
  else:
    moveRight()
  if isThere(Demon):
    attack()
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Synthesis baseline

```
def run():
  while(inTarget(
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Ours

```
def run():
  if inTarget(Demon):
    attack()
    moveLeft()
  else:
    moveRight()
  if isThere(Demon):
    attack()
  moveLeft()
```

Quantitative Result: Infer Programs

Sequence Accuracy

- Measure the accuracy based on code sequences

Synthesized program

```
def run():
  if A():
    x()
  else:
    while(B()):
      y()
    z()
```

Ground truth program

```
def run():
  if A():
    x()
  else:
    repeat(5):
      y()
    z()
```

Synthesized program

```
def run():
  if A():
    x()
  else:
    y()
```

Ground truth program

```
def run():
  if not A():
    y()
  else:
    x()
```

Synthesized program

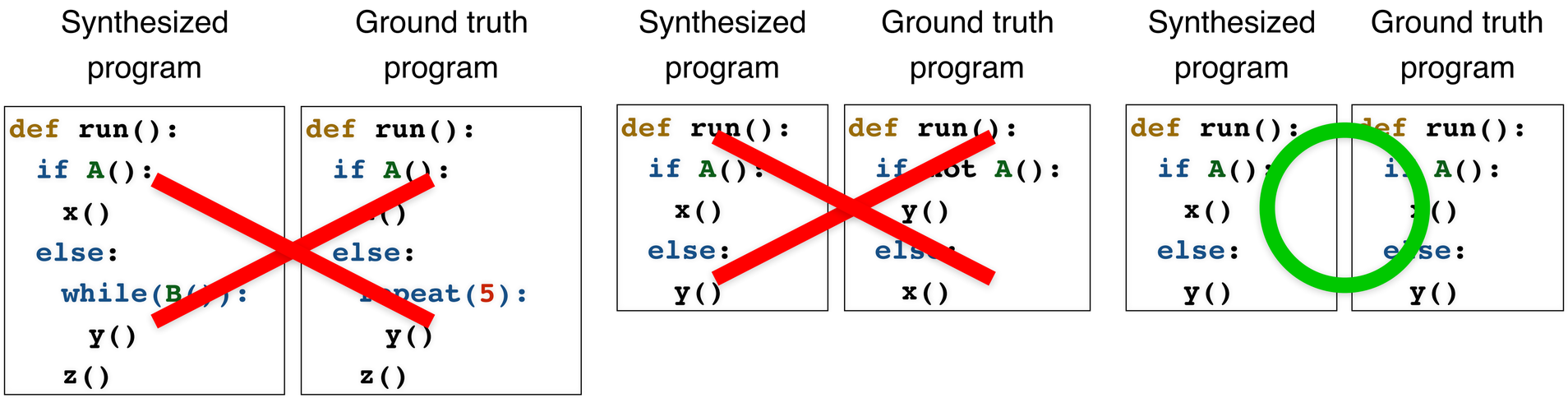
```
def run():
  if A():
    x()
  else:
    y()
```

Ground truth program

```
def run():
  if A():
    x()
  else:
    y()
```

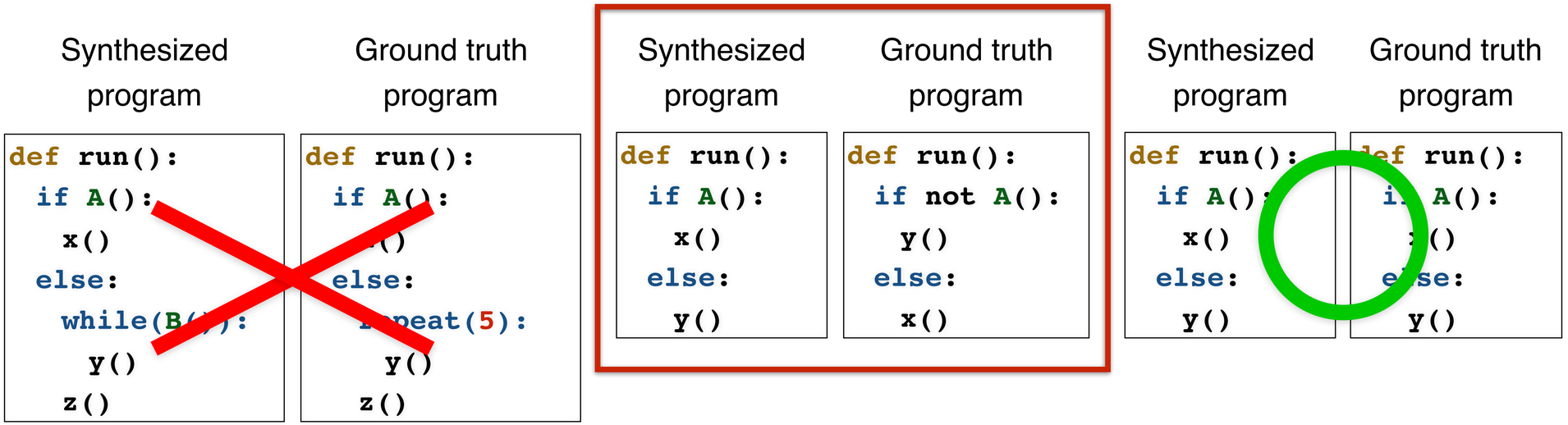
Sequence Accuracy

- Measure the accuracy based on code sequences



Sequence Accuracy

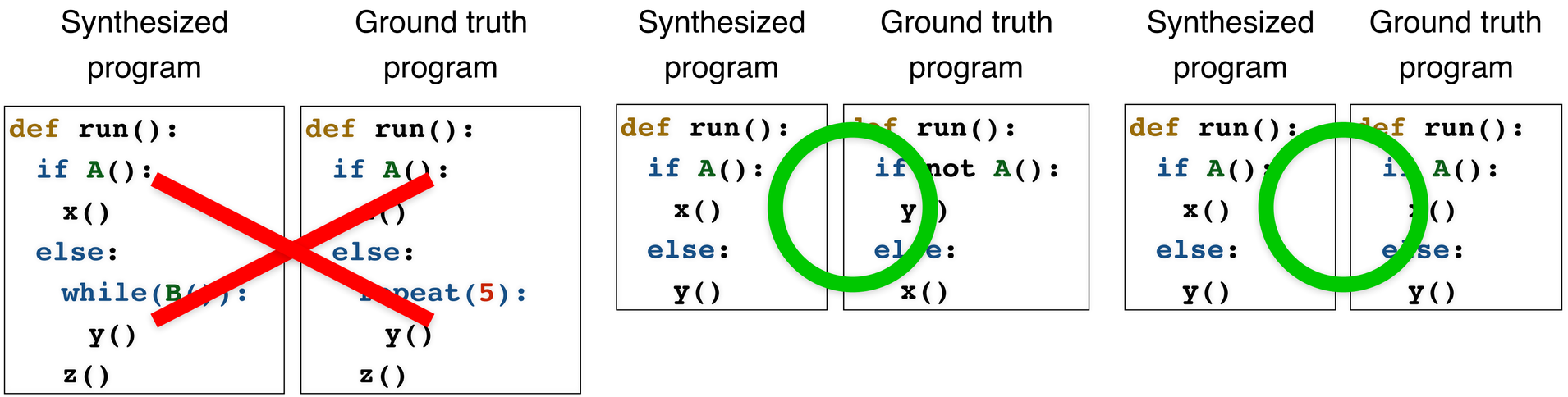
- Measure the accuracy based on code sequences



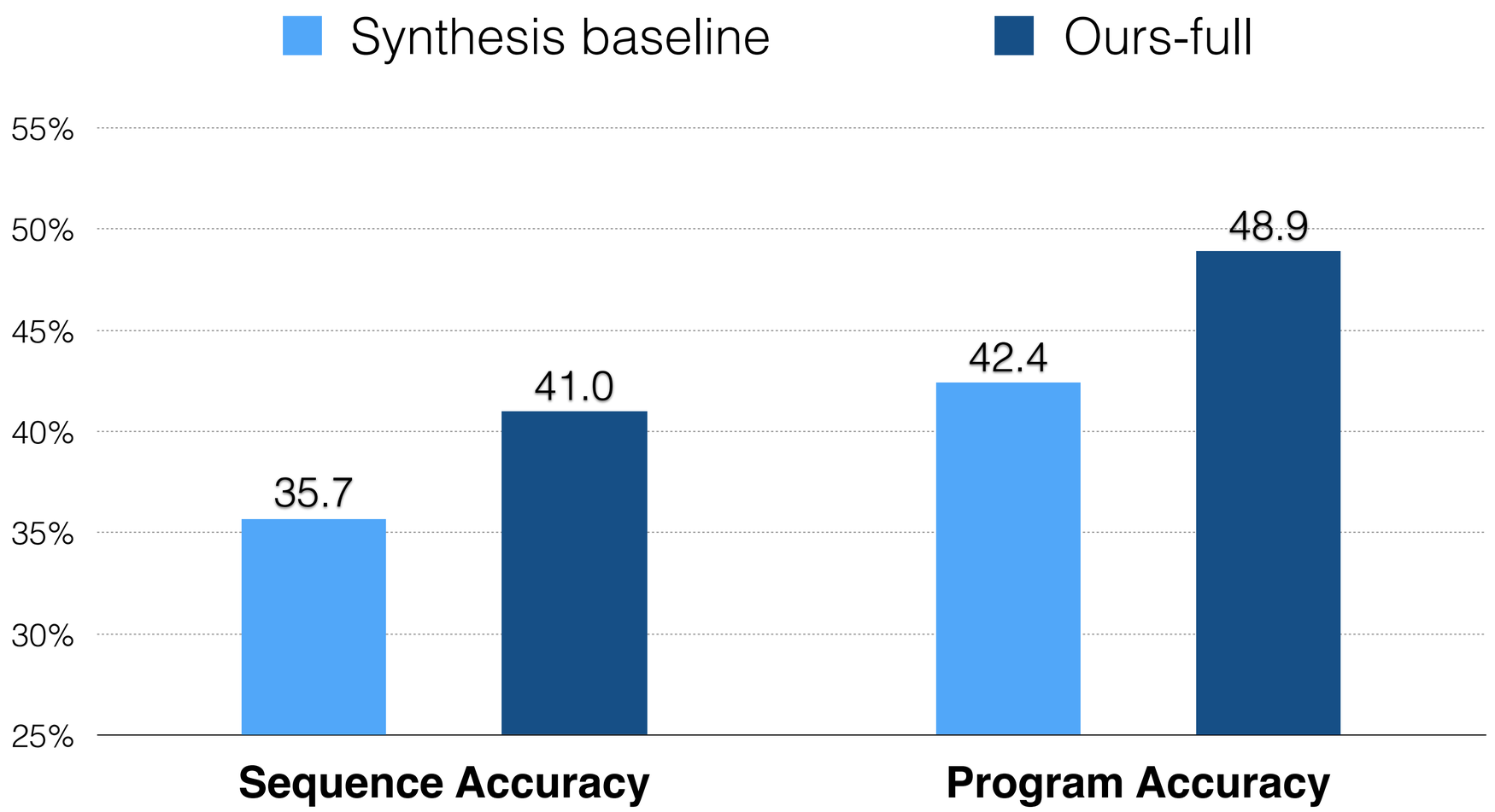
Program aliasing
Different codes with identical program semantics

Program Accuracy

- Compare programs in the program semantic space
  - With some assumptions
    - ex. termination of loops

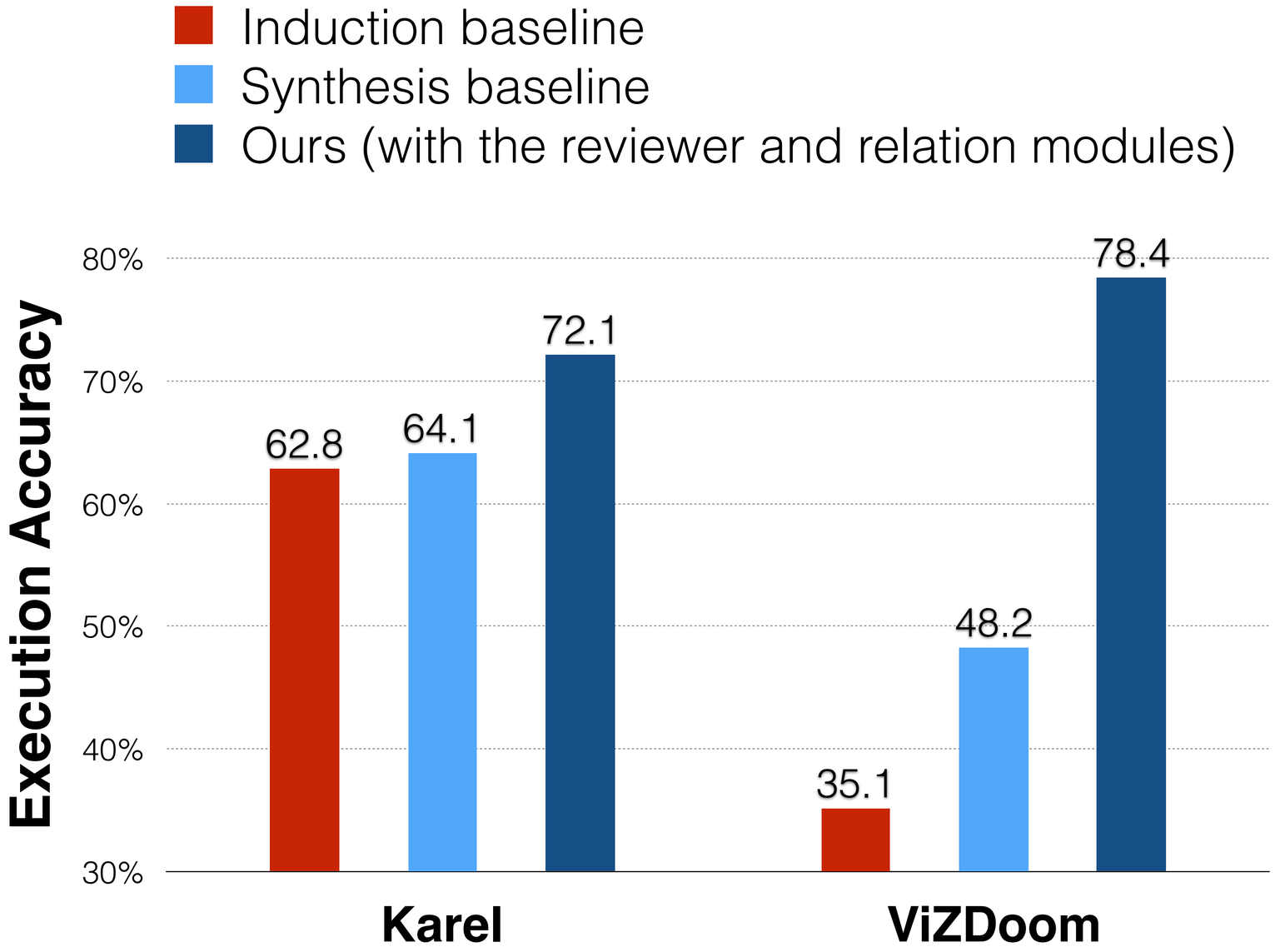


Quantitative Result: Infer Programs

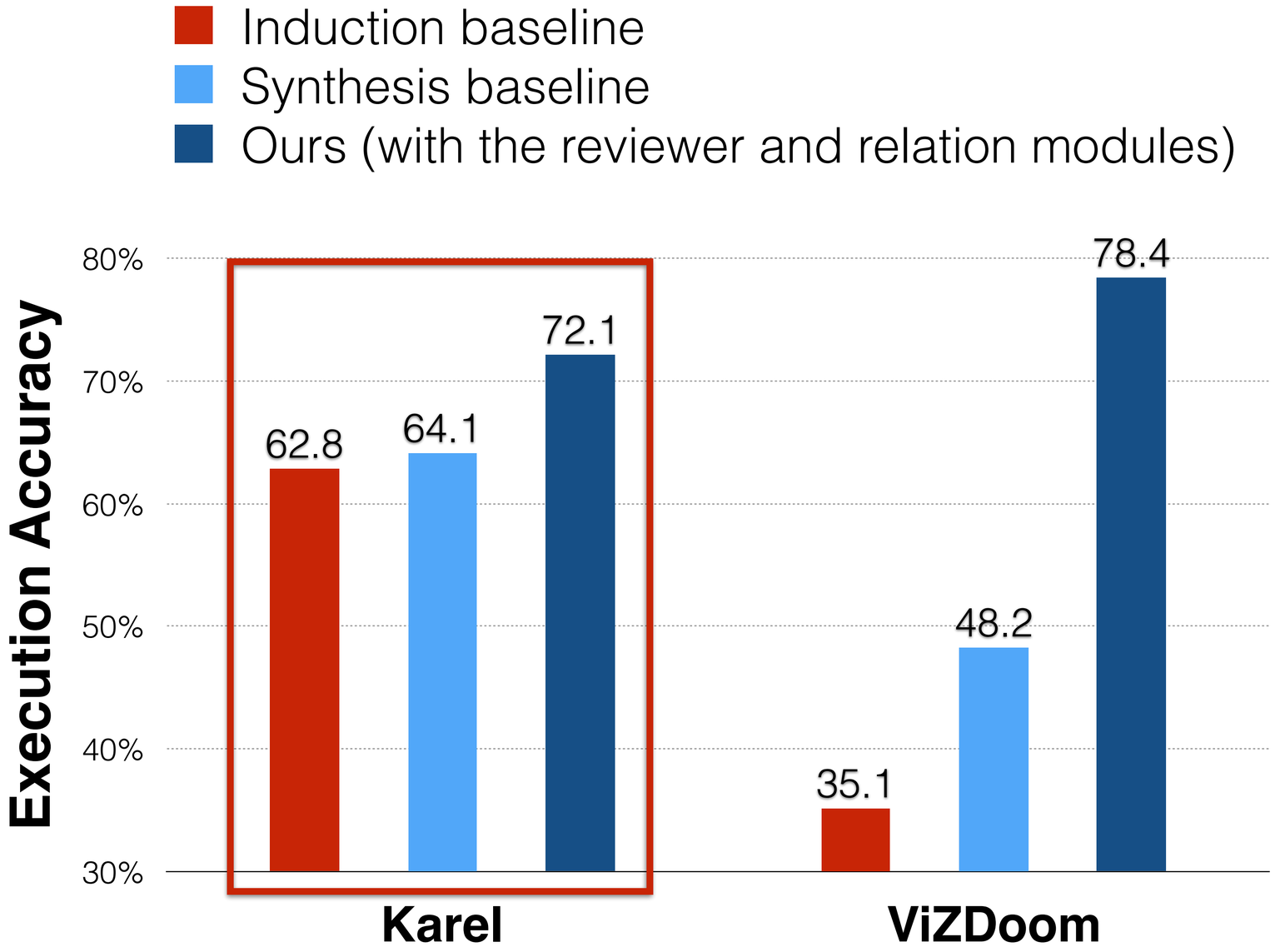


Quantitative Result: Execution

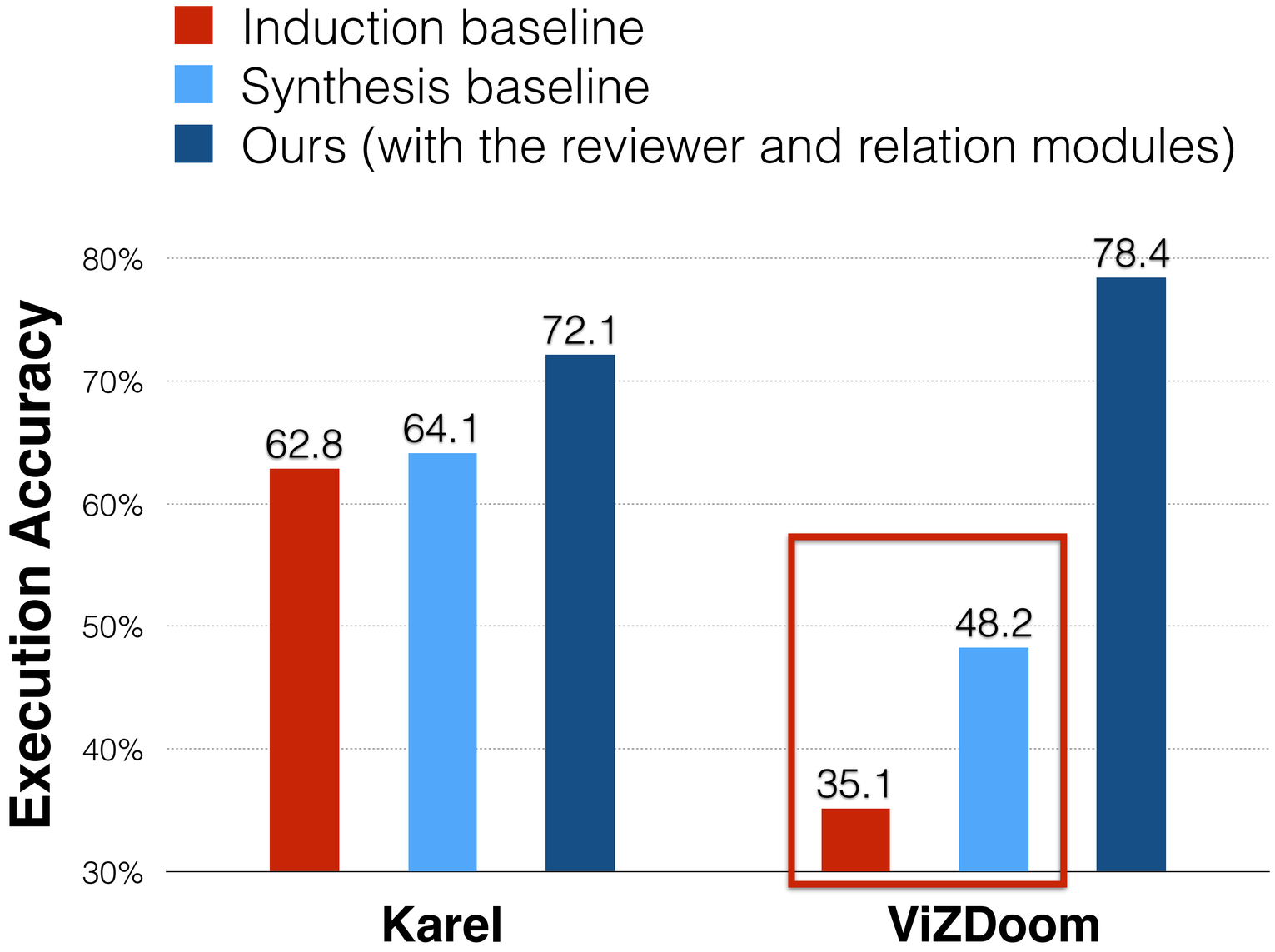
Quantitative Result: Execution



Quantitative Result: Execution

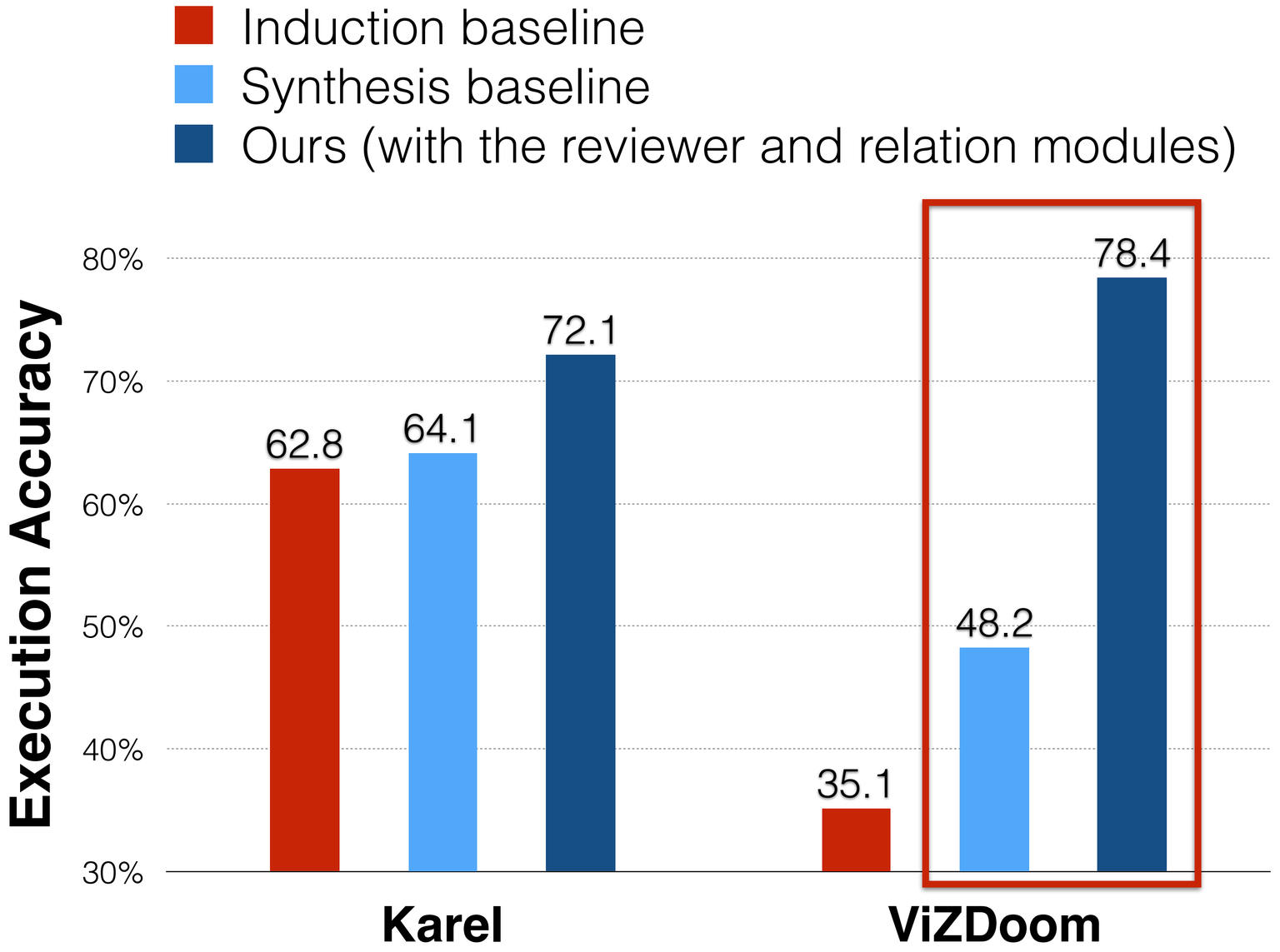


Quantitative Result: Execution



Synthesize programs to describe behaviors

Quantitative Result: Execution



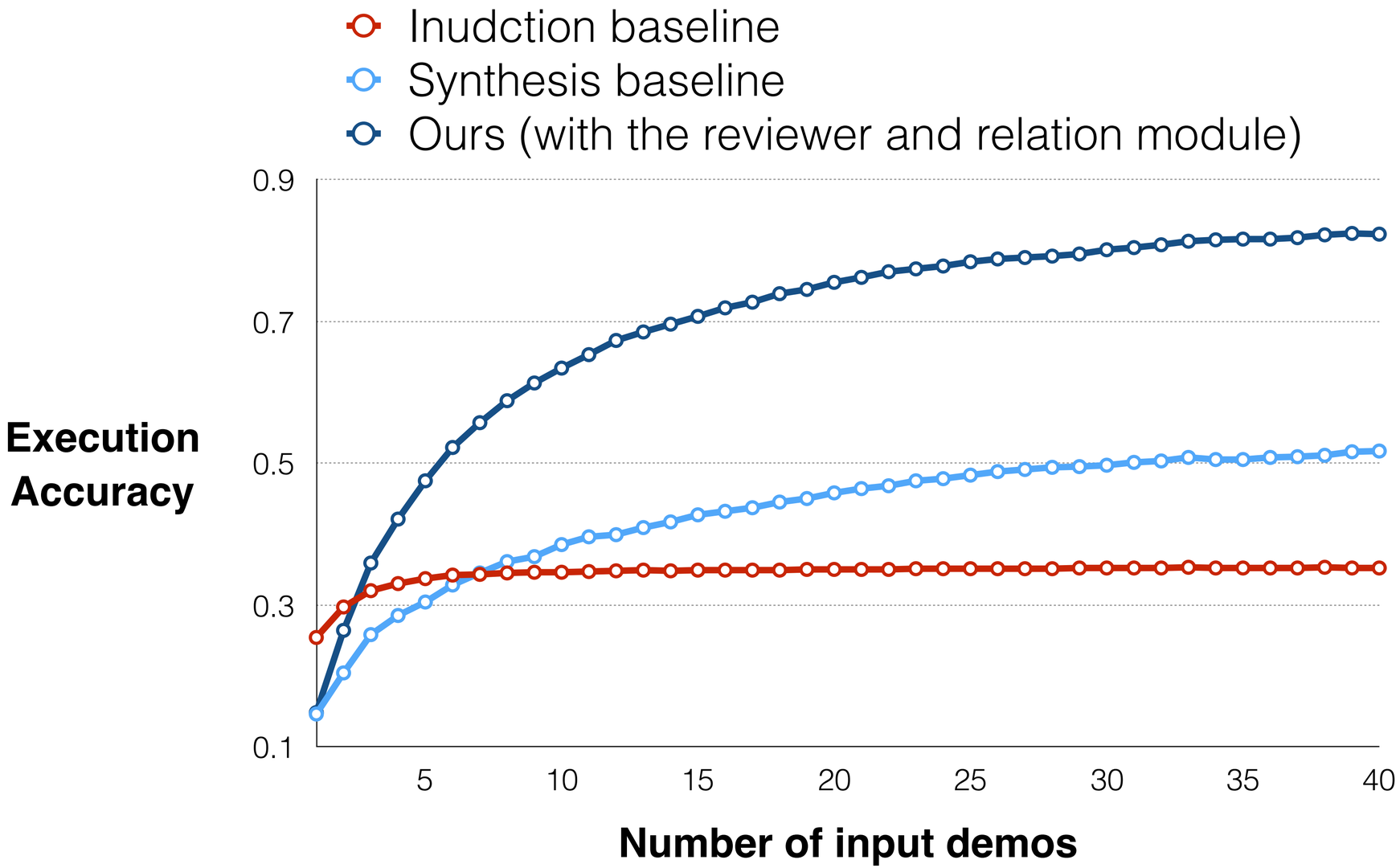
Synthesize programs to describe behaviors

Reviewer module

Relation module

More Results

Effect of Additional Demos

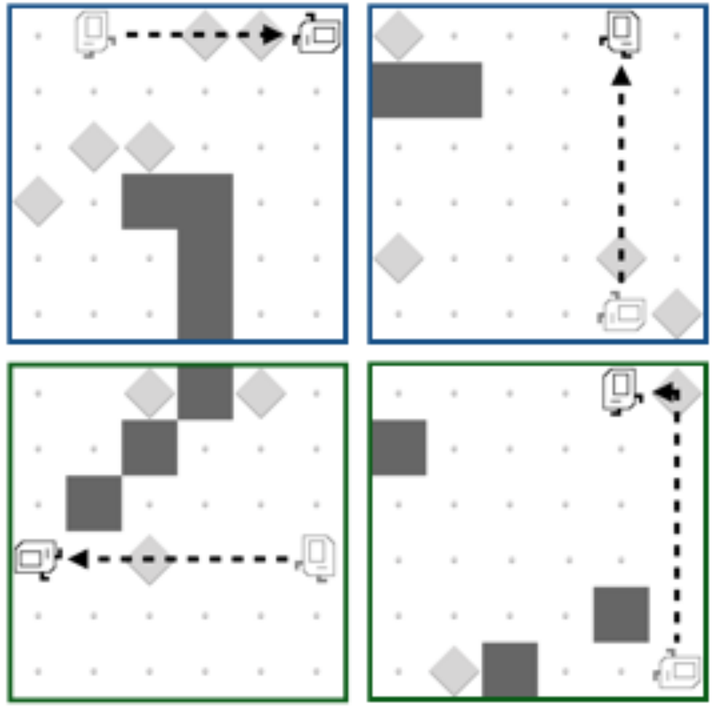


Incomplete Seen Denominations

The seen demos do not completely capture **the underlying behavior**

Underlying Program

```
def run():
  turnRight()
  turnRight()
  while frontIsClear():
    move()
  if markersPresent():
    turnLeft()
    move()
  else:
    turnRight()
```

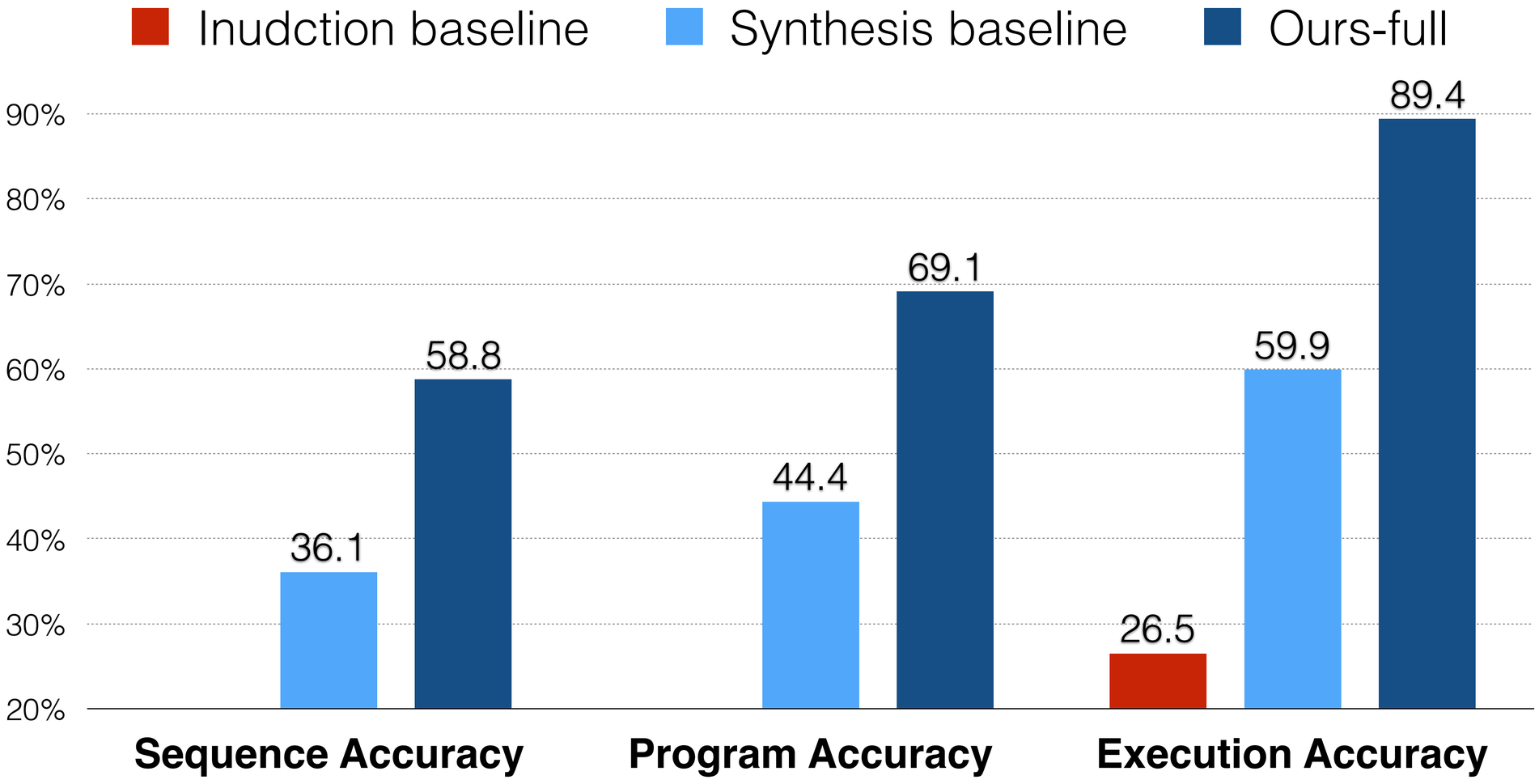


Synthesized Program

```
def run():
  turnRight()
  turnRight()
  while frontIsClear():
    move()
  else:
    turnRight()
```

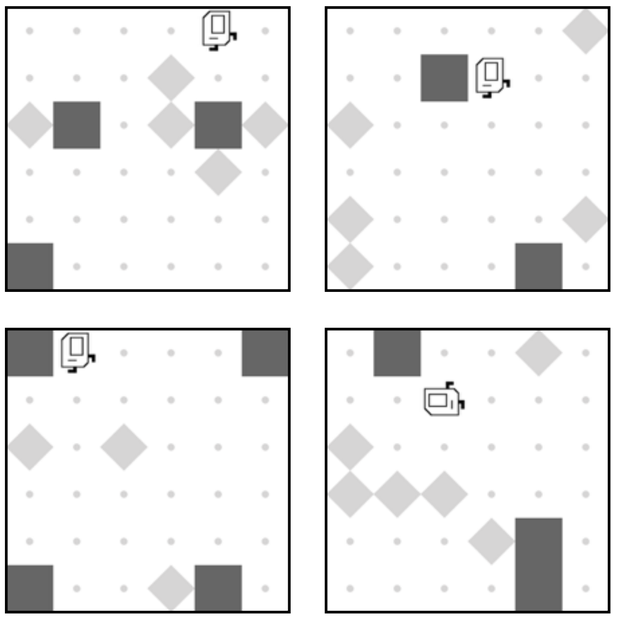
If-else experiment

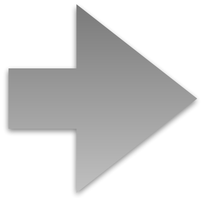
Each program: **single if-else statement** with two branching consequences



Conclusion

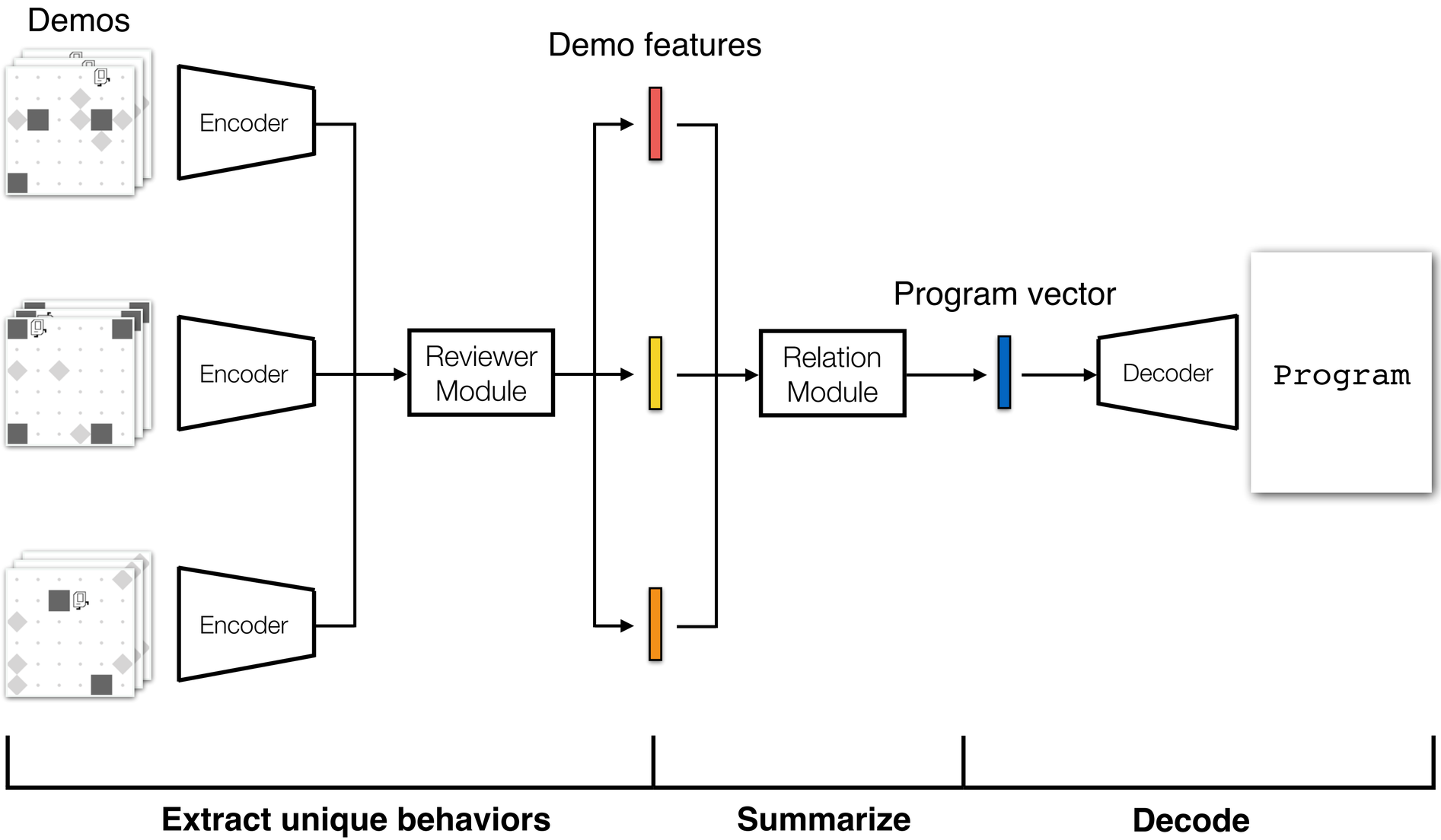
Neural Program Synthesis from Diverse Demonstration Videos



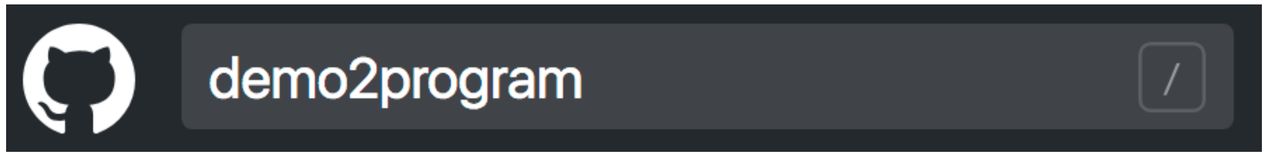


```
def run()
   if frontIsClear():
      move()
   else:
      turnLeft()
   move()
   turnLeft
   repeat(2):
      turnRight()
      putMarker()
```

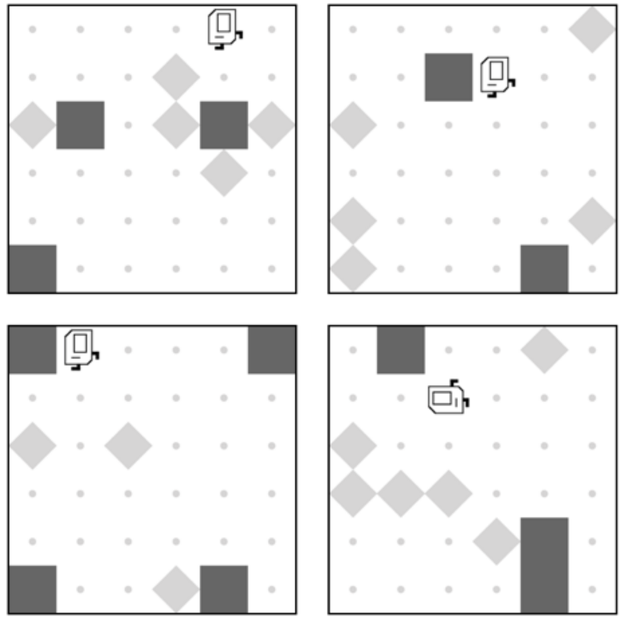
Neural Program Synthesis from Diverse Demonstration Videos



Codes, datasets, and checkpoints are available at



Questions?



```
def run()
  if frontIsClear():
    move()
  else:
    turnLeft()
  move()
  turnLeft()
  repeat(2):
    turnRight()
    putMarker()
```