

1) Analogical Reasoning in Natural Language (2022-2023)



Life is a Circus and We are the Clowns: Automatically Finding Analogies between Situations and Processes

Oren Sultan, Dafna Shahaf

A Base: Animal Cell

The plasma membrane encloses the animal cell. It controls the movement of materials into and out of the cell. The Nucleus controls the activities of the cell. These cellular activities require energy. The Mitochondria extract energy from food molecules to provide the energy needs of the cell. Animal cells must also synthesize a variety of proteins and other organic molecules necessary for growth and repair. Ribosomes produce these proteins. The cell may use these proteins or move them out of the cell for use in other cells. To move organic molecules, the cell contains a complex system of membranes that create channels within the cell. This system of membranes is called the endoplasmic reticulum.

B Target: Factory

Security guards monitor the doors of the factory. They control the movement of people into and out of the factory. Factory activities may be coordinated by a control center. These activities require energy. The electrical generators in the factory provide energy. The factory synthesizes products from raw materials using machines. The factory has hallways to move products through it.

What controls something? (B)
Who controls something? (T)

What synthesizes something? (B, T)
What uses something? (B, T)
What moves something? (B, T)

C Base (B) Target (T)

'the activities of the cell' 'products'

'proteins' 'this proteins' 'energy'

'the energy needs of the cell' 'energy'

'plasma membrane' 'the plasma membrane'

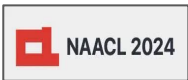
'the cell' 'cell'

'the mitochondria' 'mitochondria'

'these activities' 'activities'

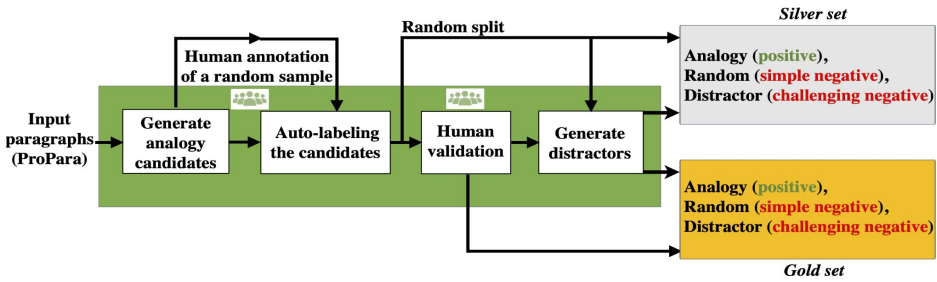
'electrical generators' 'the electrical generators in the factory'

'security guards' 'factory activities'



ParallelPARC: A Scalable Pipeline for Generating Natural-Language Analogies

Oren Sultan, Yonatan Bitton, Ron Yosef, Dafna Shahaf



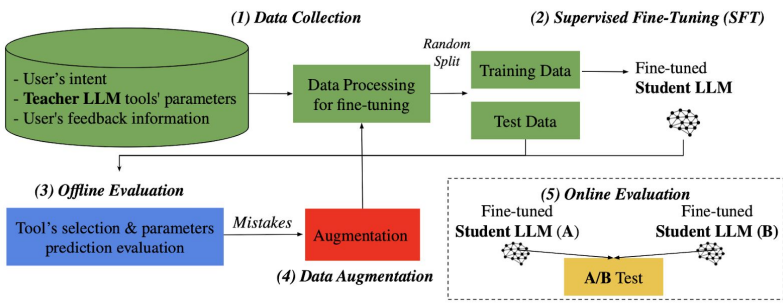
Base	Target	Similar Relations
<p>Title: How does a solar panel work?</p> <p>Domain: Engineering</p> <p>Paragraph: solar energy <i>powers</i> an electric current within a solar panel. The photovoltaic cells within the panel <i>convert</i> the energy from the sun into electricity. The electrical wires then <i>spread</i> this power throughout the panel. The electric current is then used to <i>power</i> whatever the panel is connected to.</p>	<p>Title: How does photosynthesis occur?</p> <p>Domain: Natural Science</p> <p>Paragraph: Photosynthesis occurs when sunlight <i>powers</i> chemical reactions within the chloroplasts of a plant. The chloroplasts are able to <i>transform</i> the energy from the sunlight into usable energy for the plant. This energy is then used to produce nutrients for the plant, which are then <i>distributed</i> throughout the plant.</p>	<p>(solar energy, <i>powers</i>, electric current) (sunlight, <i>powers</i>, chemical reactions)</p> <p>(photovoltaic cells, <i>convert</i>, energy) (chloroplasts, <i>transform</i>, energy)</p> <p>(electrical wires, <i>spread</i>, power) (plants, <i>distribute</i>, nutrients)</p>

2) Combining LLMs with tools – A neuro-symbolic approach (2024-2025)



Visual Editing with LLM-based Tool Chaining: An Efficient Distillation Approach for Real-Time Applications

Oren Sultan, Alex Khasin, Guy Shiran, Asnat Greenstein-Messica, Dafna Shahaf



Adjust

Selective adjust

Filter

```
{
  "exposure": 0,
  "contrast": 10,
  "brightness": 10,
  "highlights": 20,
  "shadows": -10,
  "saturation": 15,
  "vibrance": 15,
  "temperature": 30,
  "tint": 10,
  "hue": 0,
  "bloom": 0,
  "sharpen": 0,
  "structure": 0,
  "linearOffset": 0
}
```

```
{
  "red": {"saturation": 20, "luminance": 10},
  "orange": {"saturation": 30, "luminance": 20},
  "yellow": {"saturation": 40, "luminance": 30},
  "green": {"saturation": -20, "luminance": 0},
  "cyan": {"saturation": -20, "luminance": 0},
  "blue": {"saturation": 0, "luminance": 0}
}
```

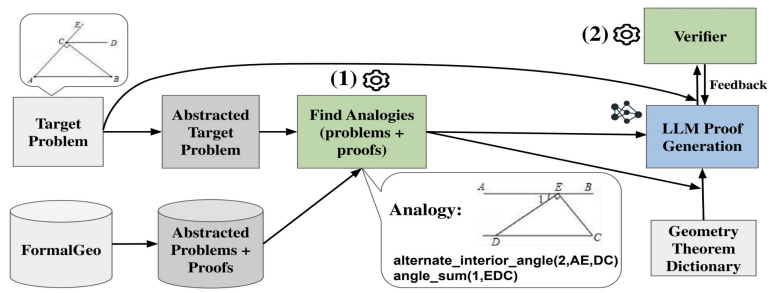
```
{
  "name": "faded_HighNoon",
  "intensity": 40
}
```

“Golden hour”



Towards Reliable Proof Generation with LLMs: A Neuro-Symbolic Approach

Oren Sultan, Eitan Stern, Dafna Shahaf



Problem:

Description: " $\angle ABC = 40^\circ$, $CD \parallel AB$, BC is perpendicular to AC . Find the measure of $\angle ECD$ "

Construction: $Shape(CA, AB, BC)$, $Shape(EC, CD)$...

Construction (extended): $Shape(AB, BC, CA)$, $Shape(BC, CA, AB)$...

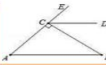
Conditions: $Equal(MeasureOfAngle(ABC), 40)$, $ParallelBetweenLine(CD, AB)$...

Goal: $Value(MeasureOfAngle(ECD))$

Answer: 50

Proof:

- 1) $parallel_property_alternate_interior_angle(1, CD, AB)$
- 2) $angle_addition(1, ECD, DCB)$
- 3) $adjacent_complementary_angle(1, ECB, BCA)$



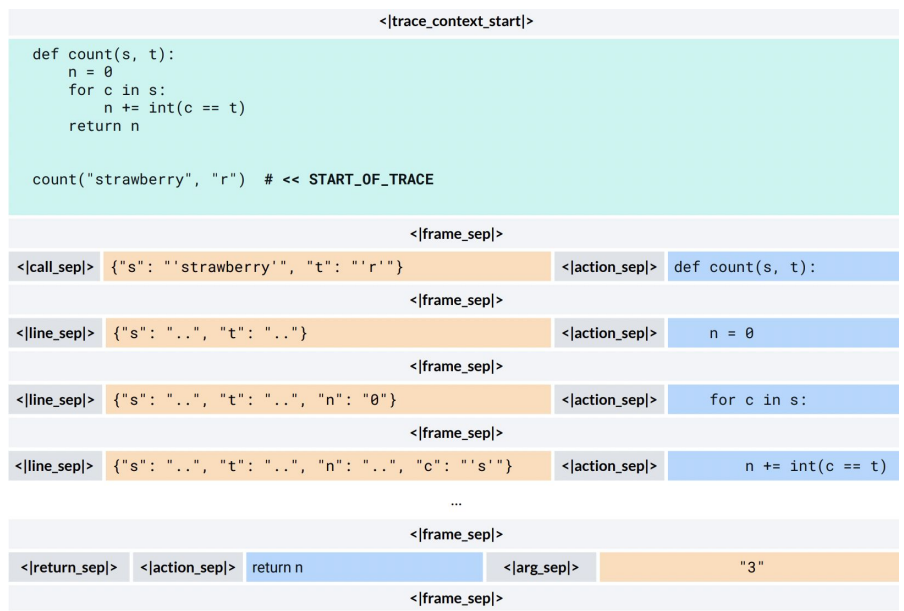
Theorem Dictionary (GDL):

```
parallel_property_alternate_interior_angle(AB, CD):
{
  1: {
    premises:
      ParallelBetweenLine(AB, CD) & Line(AD),
    conclusions: Equal(MeasureOfAngle(BAD), ...)
  },
  2: { ... },
  ...
}
angle_addition(ABC, CBD): {
  1: { ... },
  ...
}
```

3) Code World Models (CWM) and the Halting Problem (2025)

CWM: An Open-Weights LLM for Research on Code Generation with World Models

Meta FAIR CodeGen Team, **Oren Sultan**



LLMs versus the Halting Problem: Revisiting Program Termination Prediction

Oren Sultan, Jordi Armengol-Estapé, Pascal Kesseli, Julien Vanegue, Dafna Shahaf, Peter O'Hearn, Yossi Adi

