Assignment 2

DS685

A.I. for Robotics

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1. Introduction

This assignment focused on converting a visual robot demonstration into symbolic planning models using PDDL (Planning Domain Definition Language). The idea was to simulate how a robot observes a task and then expresses the task in terms of objects, predicates, and actions that a planner can reason about.

Because my Gazebo simulator was not working correctly, I created simple synthetic frames that mimic the demonstration. These frames were passed through a Visual Language Model (VLM) to extract natural-language descriptions. From those descriptions, I constructed a PDDL domain and three problem files, and then validated them using the Unified Planning library.

The overall workflow ends up being very similar to the “Video2Plan” idea: starting with images, generating captions, interpreting symbolic relationships, and producing a planning formulation.

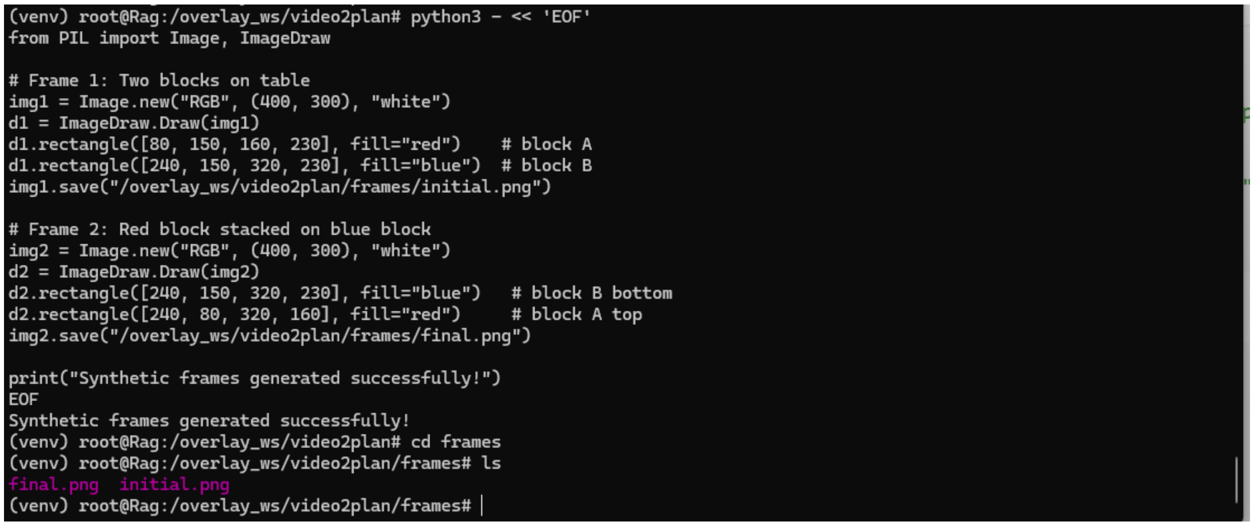
2. Generating the Demonstration Frames

To represent the demonstration, I created two simple images using Python’s Pillow library:

- **initial.png** – showing a red block and a blue block placed separately on a white surface
- **final.png** – showing the same two blocks, but with the red block now stacked on top of the blue block

Both images were stored inside:

/overlay_ws/video2plan/frames

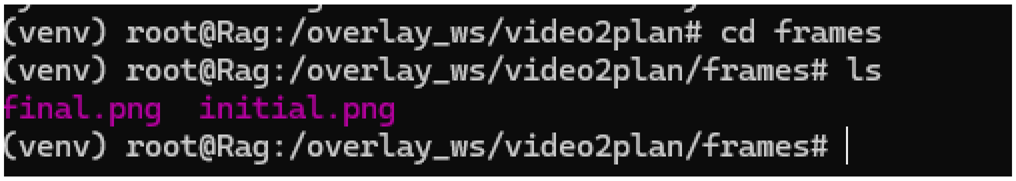


```
(venv) root@Rag:/overlay_ws/video2plan# python3 - << 'EOF'
from PIL import Image, ImageDraw

# Frame 1: Two blocks on table
img1 = Image.new("RGB", (400, 300), "white")
d1 = ImageDraw.Draw(img1)
d1.rectangle([80, 150, 160, 230], fill="red")    # block A
d1.rectangle([240, 150, 320, 230], fill="blue")  # block B
img1.save("/overlay_ws/video2plan/frames/initial.png")

# Frame 2: Red block stacked on blue block
img2 = Image.new("RGB", (400, 300), "white")
d2 = ImageDraw.Draw(img2)
d2.rectangle([240, 150, 320, 230], fill="blue")   # block B bottom
d2.rectangle([240, 80, 320, 160], fill="red")     # block A top
img2.save("/overlay_ws/video2plan/frames/final.png")

print("Synthetic frames generated successfully!")
EOF
Synthetic frames generated successfully!
(venv) root@Rag:/overlay_ws/video2plan# cd frames
(venv) root@Rag:/overlay_ws/video2plan/frames# ls
final.png  initial.png
(venv) root@Rag:/overlay_ws/video2plan/frames# |
```



```
(venv) root@Rag:/overlay_ws/video2plan# cd frames
(venv) root@Rag:/overlay_ws/video2plan/frames# ls
final.png  initial.png
(venv) root@Rag:/overlay_ws/video2plan/frames# |
```

Fig -Frame configuration

3. Caption Extraction with a Visual Language Model

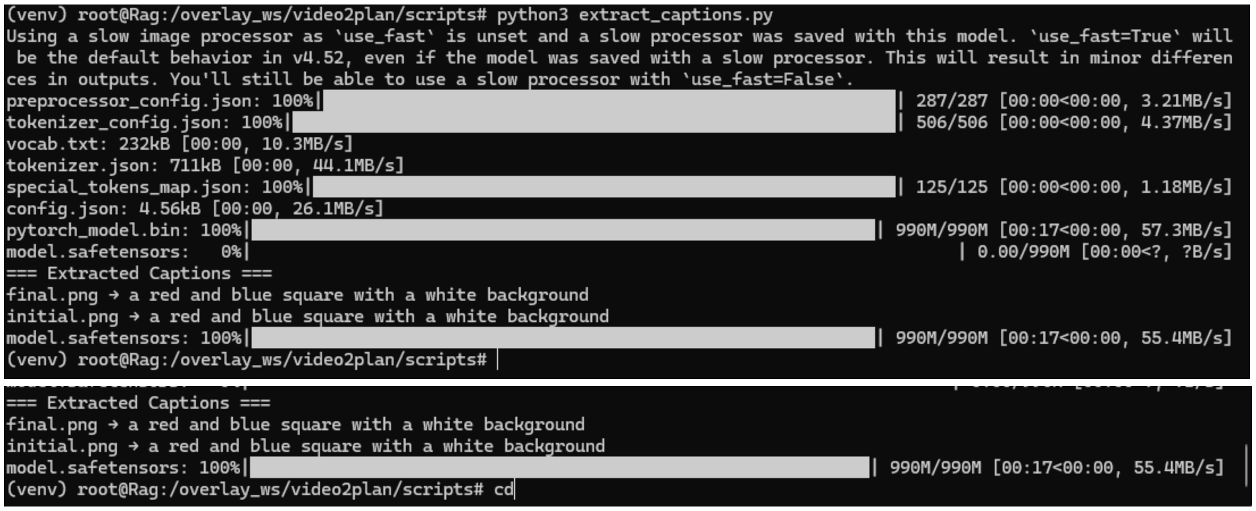
To extract textual descriptions of each frame, I used a BLIP-based image captioning script. When executed, it generated short summaries:

initial.png → “a red and blue square with a white background”

final.png → “a red and blue square with a white background”

Even though the captions are not very detailed (since they are synthetic images), they still identify the two main components of the scene: the red object and the blue object.

A screenshot of the BLIP output confirms that the captions were extracted successfully.



```
(venv) root@Rag:/overlay_ws/video2plan/scripts# python3 extract_captions.py
Using a slow image processor as `use_fast` is unset and a slow processor was saved with this model. `use_fast=True` will
 be the default behavior in v4.52, even if the model was saved with a slow processor. This will result in minor differen
ces in outputs. You'll still be able to use a slow processor with `use_fast=False`.
preprocessor_config.json: 100%|████████████████████████████| 287/287 [00:00<00:00, 3.21MB/s]
tokenizer_config.json: 100%|███████████████████████████████| 506/506 [00:00<00:00, 4.37MB/s]
vocab.txt: 232kB [00:00, 10.3MB/s]
tokenizer.json: 711kB [00:00, 44.1MB/s]
special_tokens_map.json: 100%|█████████████████████████████| 125/125 [00:00<00:00, 1.18MB/s]
config.json: 4.56kB [00:00, 26.1MB/s]
pytorch_model.bin: 100%|██████████████████████████████| 990M/990M [00:17<00:00, 57.3MB/s]
model.safetensors:   0%|                                    | 0.00/990M [00:00<?, ?B/s]
=== Extracted Captions ===
final.png → a red and blue square with a white background
initial.png → a red and blue square with a white background
model.safetensors: 100%|██████████████████████████████| 990M/990M [00:17<00:00, 55.4MB/s]
(venv) root@Rag:/overlay_ws/video2plan/scripts# |
```

```
=== Extracted Captions ===
final.png → a red and blue square with a white background
initial.png → a red and blue square with a white background
model.safetensors: 100%|██████████████████████████████| 990M/990M [00:17<00:00, 55.4MB/s]
(venv) root@Rag:/overlay_ws/video2plan/scripts# cd
```

Fig . BLIP output …identifying frame (note – here BLIP identifies object placement same in both frames as BLIP is shallow)

4. Understanding the Scene and Identifying Predicates

Based on the captions and the visual arrangement, I identified the key symbolic concepts needed for PDDL:

- Red and blue objects → **blocks**

- The white region → **surface (table)**
- The robot must have a **gripper**
- The relationship between blocks → **stacked**, **on table**, **clear**, etc.

From this, I formulated the necessary predicates:

To express all this information symbolically, I settled on the following predicates:

- (on x y) – block *x* is on block *y*
- (on table x s) – block *x* is on surface *s*
- (clear x) – block *x* has nothing on top
- (handempty g) – the robot's gripper *g* is empty
- (holding g x) – the gripper *g* is holding block *x*
- (reachable g x) – gripper *g* can reach block *x*
- (reachablesurf g s) – gripper *g* can reach surface *s*

These predicates capture everything needed for the planner to reason about a simple block-stacking task.

These predicates describe exactly what conditions matter for a simple block-stacking task.

5. Designing the PDDL Domain

The domain file (domain.pddl) defines:

Types

block, surface, gripper

Predicates

These include all the relationships mentioned in the previous section.

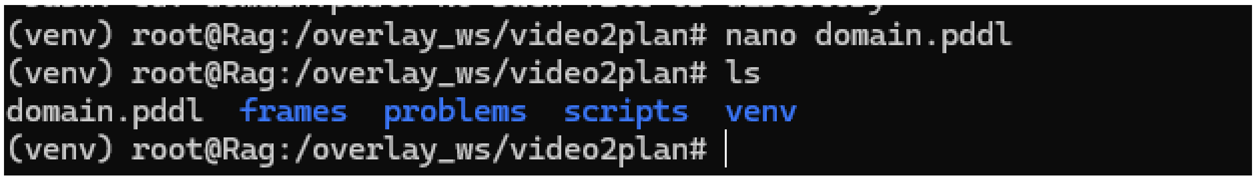
Actions

To make the domain functional, I added four actions:

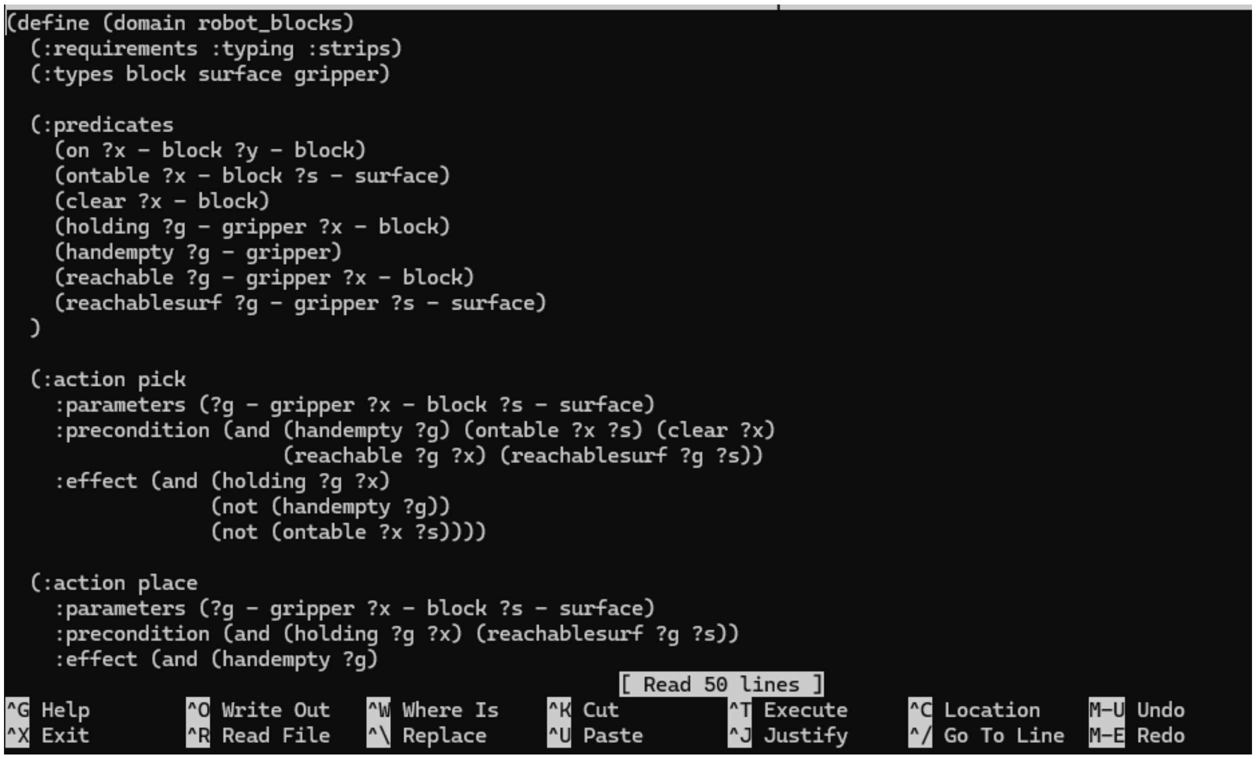
1. **pick** – picking up a block from a surface
2. **place** – placing a block back on a surface
3. **stack** – placing a block on top of another block

4. **unstack** – removing a block from another block

Each action has carefully written preconditions and effects so a planner can simulate each state transition. A screenshot of the domain.pddl file confirms the correct structure and formatting.



```
(venv) root@Rag:/overlay_ws/video2plan# nano domain.pddl
(venv) root@Rag:/overlay_ws/video2plan# ls
domain.pddl  frames  problems  scripts  venv
(venv) root@Rag:/overlay_ws/video2plan#
```



```
(define (domain robot_blocks)
  (:requirements :typing :strips)
  (:types block surface gripper)

  (:predicates
    (on ?x - block ?y - block)
    (ontable ?x - block ?s - surface)
    (clear ?x - block)
    (holding ?g - gripper ?x - block)
    (handempty ?g - gripper)
    (reachable ?g - gripper ?x - block)
    (reachablesurf ?g - gripper ?s - surface)
  )

  (:action pick
    :parameters (?g - gripper ?x - block ?s - surface)
    :precondition (and (handempty ?g) (ontable ?x ?s) (clear ?x)
                       (reachable ?g ?x) (reachablesurf ?g ?s))
    :effect (and (holding ?g ?x)
                 (not (handempty ?g))
                 (not (ontable ?x ?s))))

  (:action place
    :parameters (?g - gripper ?x - block ?s - surface)
    :precondition (and (holding ?g ?x) (reachablesurf ?g ?s))
    :effect (and (handempty ?g)
                                [ Read 50 lines ]
^G Help        ^O Write Out   ^W Where Is    ^K Cut         ^T Execute     ^C Location    M-U Undo
^X Exit        ^R Read File   ^\ Replace     ^U Paste       ^J Justify     ^/ Go To Line  M-E Redo
```

Fig. domain.pddl

6. Creating Multiple PDDL Problem Files

The assignment required at least three problem files. I created:

- **problem1.pddl:** two blocks on a table; goal: stack red on blue
- **problem2.pddl:** three blocks; goal: form a two-level stack
- **problem3.pddl:** four blocks across two tables; goal: create a taller stack

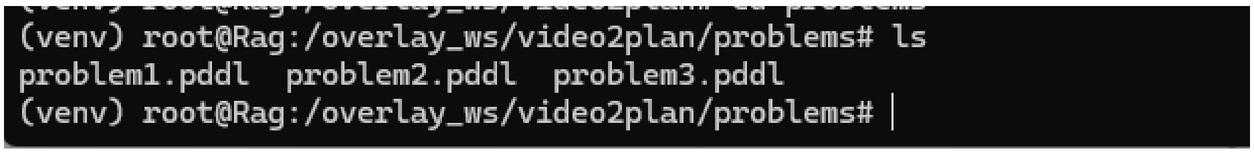
Each problem file includes:

- A list of objects
- The initial scene configuration
- Reachability assumptions for the robot gripper
- A goal description that represents the final stacked configuration

These files were saved in:

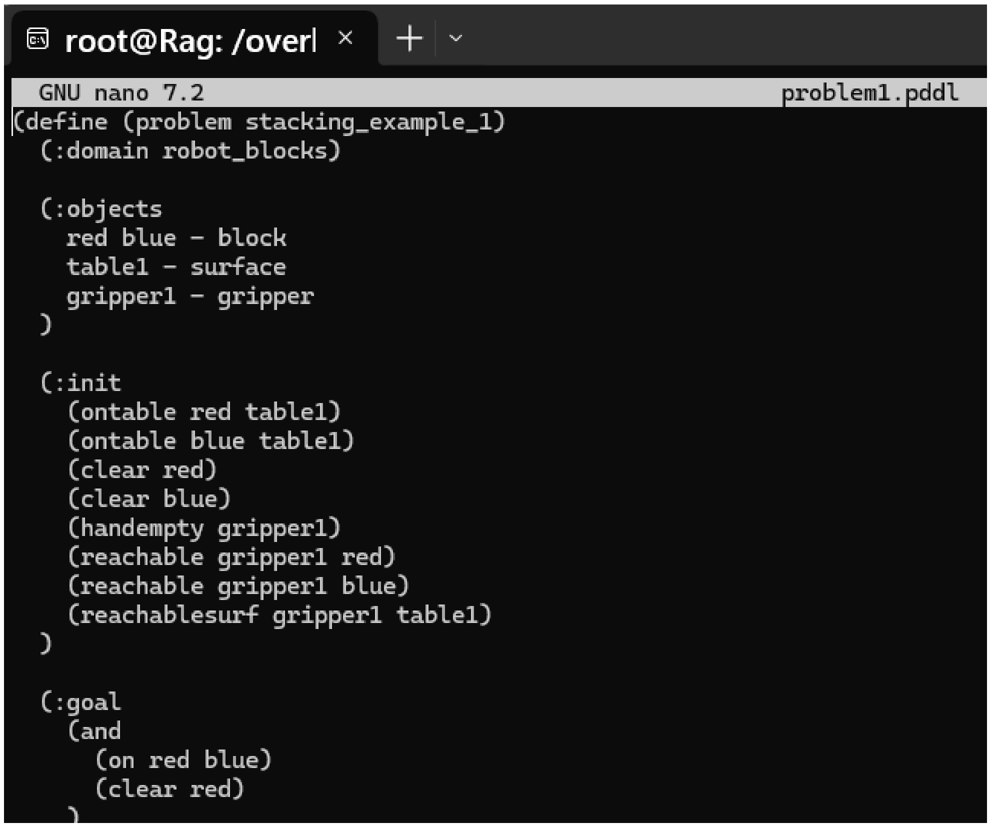
/overlay_ws/video2plan/problems

A screenshot shows all three files present.



```
(venv) root@Rag:/overlay_ws/video2plan/problems# ls
problem1.pddl  problem2.pddl  problem3.pddl
(venv) root@Rag:/overlay_ws/video2plan/problems#
```

Fig. Problems list



```
root@Rag: /overl
  GNU nano 7.2                                          problem1.pddl
(define (problem stacking_example_1)
  (:domain robot_blocks)

  (:objects
    red blue - block
    table1 - surface
    gripper1 - gripper
  )

  (:init
    (ontable red table1)
    (ontable blue table1)
    (clear red)
    (clear blue)
    (handempty gripper1)
    (reachable gripper1 red)
    (reachable gripper1 blue)
    (reachablesurf gripper1 table1)
  )

  (:goal
    (and
      (on red blue)
      (clear red)
```

Fig . Problem1.pddl

7. Validating the PDDL Using Unified Planning

I used the Unified Planning library to confirm that:

- The domain is syntactically valid
- Each problem file is compatible with the domain

Using the PDDLReader class (following the official Unified Planning notebook examples), I parsed each file in sequence:

parse_problem(domain_file, problem_file)

Once the arguments were passed in the correct order, all files loaded successfully:

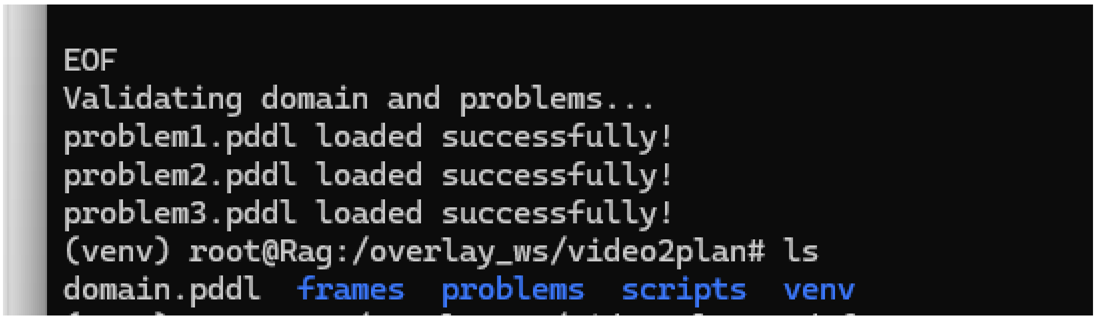
problem1.pddl loaded successfully!

problem2.pddl loaded successfully!

problem3.pddl loaded successfully!

This validation step is essential because it guarantees that the symbolic model is well-formed and ready for planners.

A screenshot confirms the successful parsing.



```
EOF
Validating domain and problems...
problem1.pddl loaded successfully!
problem2.pddl loaded successfully!
problem3.pddl loaded successfully!
(venv) root@Rag:/overlay_ws/video2plan# ls
domain.pddl  frames  problems  scripts  venv
```

8. Final Result

By combining synthetic images, VLM captioning, interpreted symbolic relations, and PDDL modeling, I completed a full demonstration-to-planning pipeline:

1. Created demonstration frames
2. Extracted natural-language descriptions using BLIP
3. Mapped the scene to symbolic predicates
4. Wrote a PDDL domain describing actions and relationships
5. Created multiple problem files representing different tasks
6. Validated everything using the Unified Planning library

All required screenshots have been collected to document each step.

Conclusion

This exercise helped me connect the visual side of robotics with symbolic planning. By turning simple images into predicates, defining a domain, and validating multiple problem files, I got a practical sense of how a planner reasons about actions. Despite a few formatting issues along the way, the full pipeline worked smoothly once everything was aligned. Overall, it was a useful introduction to building planning models directly from visual input.