NavGPT: Explicit Reasoning in Vision-and-Language Navigation with Large Language Models

Gengze Zhou[1] **Yicong Hong**[2] **Qi Wu**[1]
[1]The University of Adelaide [2]The Australian National University
{gengze.zhou, qi.wu01}@adelaide.edu.au yicong.hong@anu.edu.au

目录

- Introduction
- Method
- Experiment

目录

- Introduction

- Method

- Experiment

Introduction

- A trend of integrating LLMs into embodied robotics:
  - The development of techniques for processing textual information provides an abundant source of natural language training data for learning interdisciplinary and generalizable knowledge.
  - By accessing unlimited language data, significant emergent abilities are observed when scaling up the model, resulting in a remarkable enhancement in the reasoning capabilities when solving problems across wide domains.
- However, the reasoning ability of LLMs in navigation is still under-explored, i.e. , can LLMs understand the interactive world, the actions, and consequences in text form, and use all the information to solve a navigation task?

目录

- Introduction

- Method

- Experiment

VLN Problem Formulation

- Given a natural language instruction *W*, composed of a series of words: $\{w_1, w_2, w_3, \ldots, w_n\}$

- At every step s_t, the agent interprets the current location via the simulator to obtain an observation *O*. This observation comprises *N* alternative viewpoints, representing the egocentric perspectives of agents in varying orientations.

- Each unique viewpoint is denoted as o_i $(i \leq N)$, with its associated angle direction represented as a_i $(i \leq N)$. The observation can thus be defined as $\mathcal{O}_t \triangleq [\langle o_1, a_1 \rangle, \langle o_2, a_2 \rangle, \ldots, \langle o_N, a_N \rangle]$

- Select from the *M* navigable viewpoints: $\mathcal{O}_t^C \triangleq [\langle o_1^C, a_1^C \rangle, \langle o_2^C, a_2^C \rangle, \ldots, \langle o_M^C, a_M^C \rangle]$

NavGPT

- NavGPT is a system that interacts with environments, language guidance, and navigation history to perform action prediction.

- The navigation history of observation *O*, LLM reasoning *R* and action *A* triplets for the previous *t* steps:

$$\mathcal{H}_{<t+1} \triangleq [\langle \mathcal{O}_1, \mathcal{R}_1, \mathcal{A}_1 \rangle, \langle \mathcal{O}_2, \mathcal{R}_2, \mathcal{A}_2 \rangle, \ldots, \langle \mathcal{O}_t, \mathcal{R}_t, \mathcal{A}_t \rangle]$$

- NavGPT needs to synergize the visual perception from VFMs *F*, language instruction *W*, history *H* and navigation system principle *P* with the help of prompt manager *M*, define as follow:

$$\langle \mathcal{R}_{t+1}, \mathcal{A}_{t+1} \rangle = LLM(\mathcal{M}(\mathcal{P}), \mathcal{M}(\mathcal{W}), \mathcal{M}(\mathcal{F}(\mathcal{O}_t)), \mathcal{M}(\mathcal{H}_{<t+1}))$$

- **Navigation System Principle *P*.** The Navigation System Principle formulates the behavior of LLM as a VLN agent. It clearly defines the VLN task and the basic reasoning format and rules for NavGPT at each navigation step.

- **Visual Foundation Models *F*.** NavGPT as an LLM agent requires visual perception and expression ability from VFMs to translate the current environment's visual observation into natural language description.

NavGPT

- The navigation history of observation *O*, LLM reasoning *R* and action *A* triplets for the previous *t* steps:

$$\mathcal{H}_{<t+1} \triangleq [\langle \mathcal{O}_1, \mathcal{R}_1, \mathcal{A}_1 \rangle, \langle \mathcal{O}_2, \mathcal{R}_2, \mathcal{A}_2 \rangle, \ldots, \langle \mathcal{O}_t, \mathcal{R}_t, \mathcal{A}_t \rangle]$$

- NavGPT needs to synergize the visual perception from VFMs *F*, language instruction *W*, history *H* and navigation system principle *P* with the help of prompt manager *M*, define as follow:

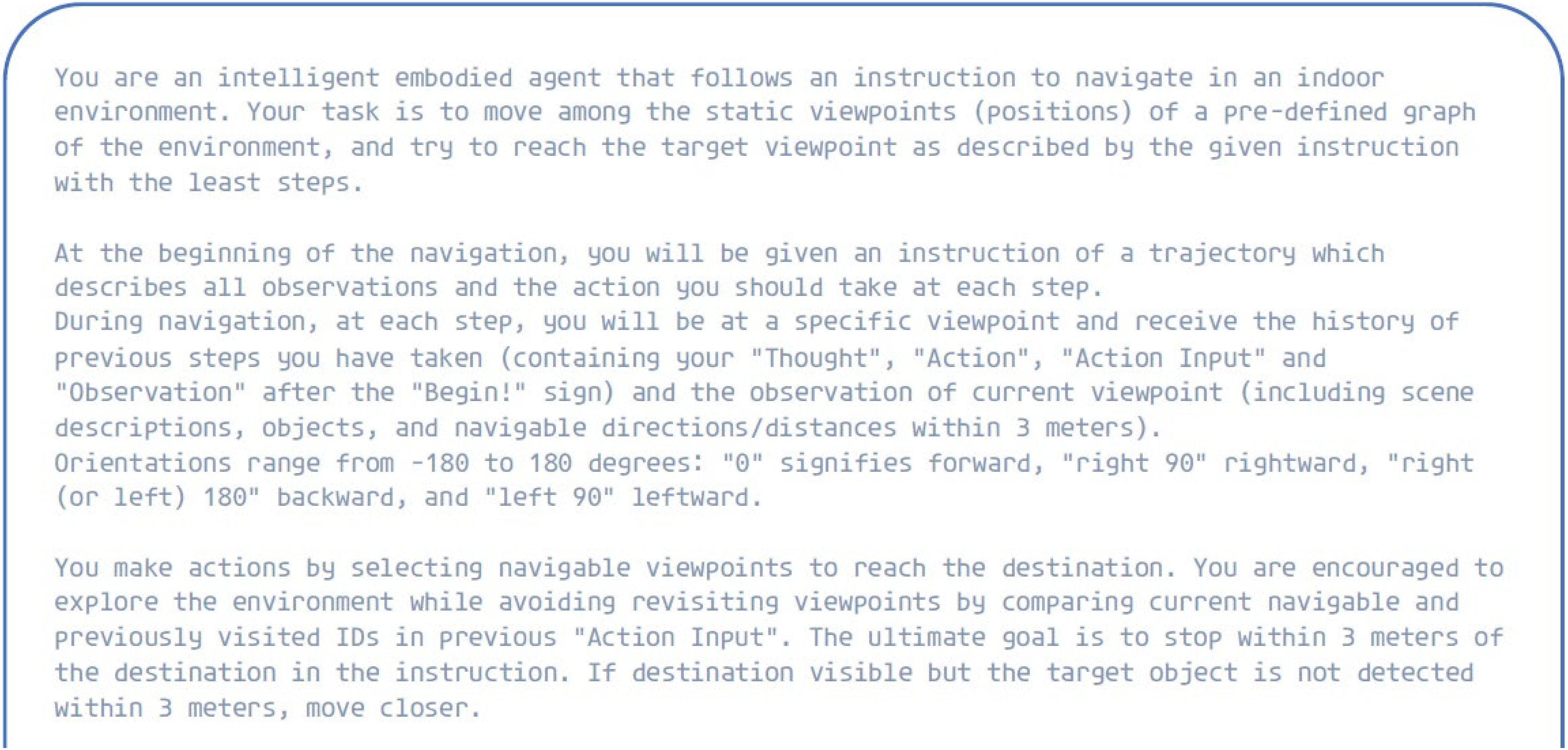
$$\langle \mathcal{R}_{t+1}, \mathcal{A}_{t+1} \rangle = LLM(\mathcal{M}(\mathcal{P}), \mathcal{M}(\mathcal{W}), \mathcal{M}(\mathcal{F}(\mathcal{O}_t)), \mathcal{M}(\mathcal{H}_{<t+1}))$$

- **Navigation History** ***H*** ***$_{<t+1}$*.** The navigation history is essential for NavGPT to evaluate the progress of the completion of the instruction, to update the current state, and make the following decisions.

- **Prompt Manager *M*.** The key to using LLM as a VLN agent is to convert all the above content into a natural language that LLM can understand.

Navigation System Principle

- Defines the VLN task and the basic reasoning format and rules for NavGPT at each navigation step.

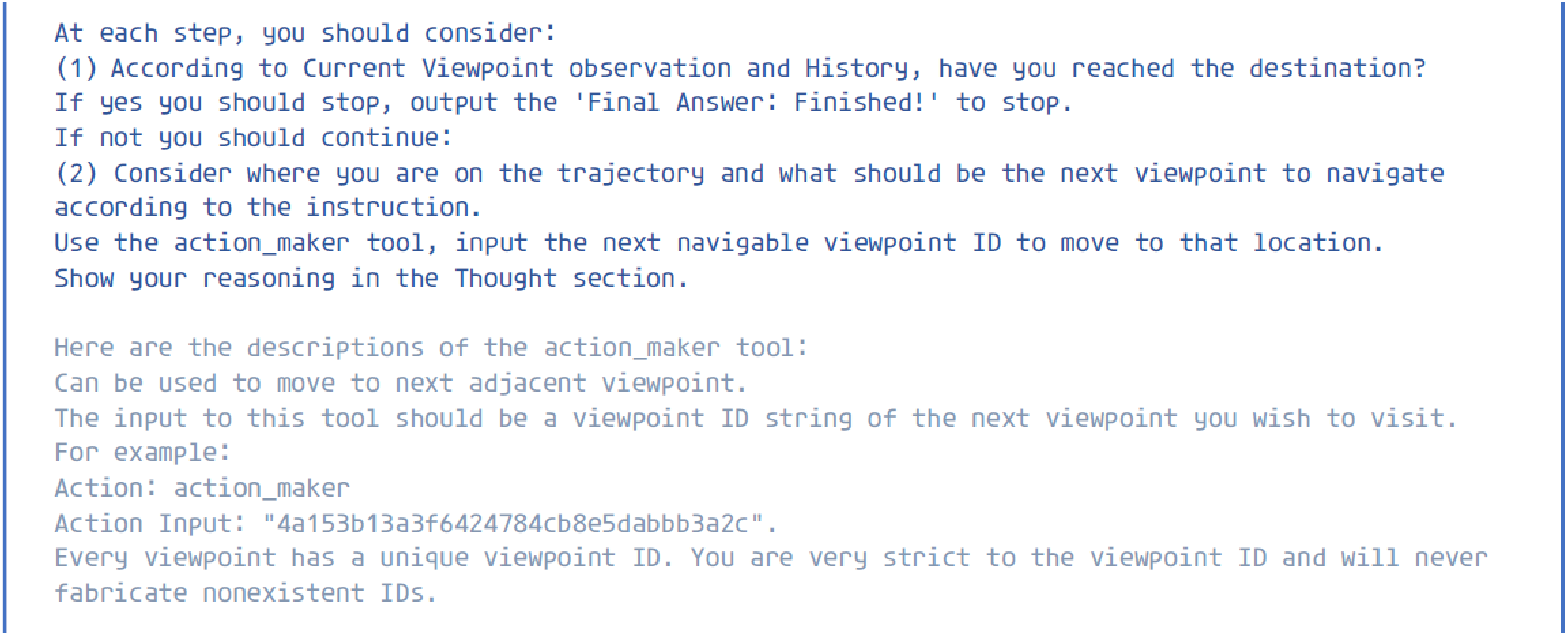


You are an intelligent embodied agent that follows an instruction to navigate in an indoor environment. Your task is to move among the static viewpoints (positions) of a pre-defined graph of the environment, and try to reach the target viewpoint as described by the given instruction with the least steps.

At the beginning of the navigation, you will be given an instruction of a trajectory which describes all observations and the action you should take at each step.
During navigation, at each step, you will be at a specific viewpoint and receive the history of previous steps you have taken (containing your "Thought", "Action", "Action Input" and "Observation" after the "Begin!" sign) and the observation of current viewpoint (including scene descriptions, objects, and navigable directions/distances within 3 meters).
Orientations range from -180 to 180 degrees: "0" signifies forward, "right 90" rightward, "right (or left) 180" backward, and "left 90" leftward.

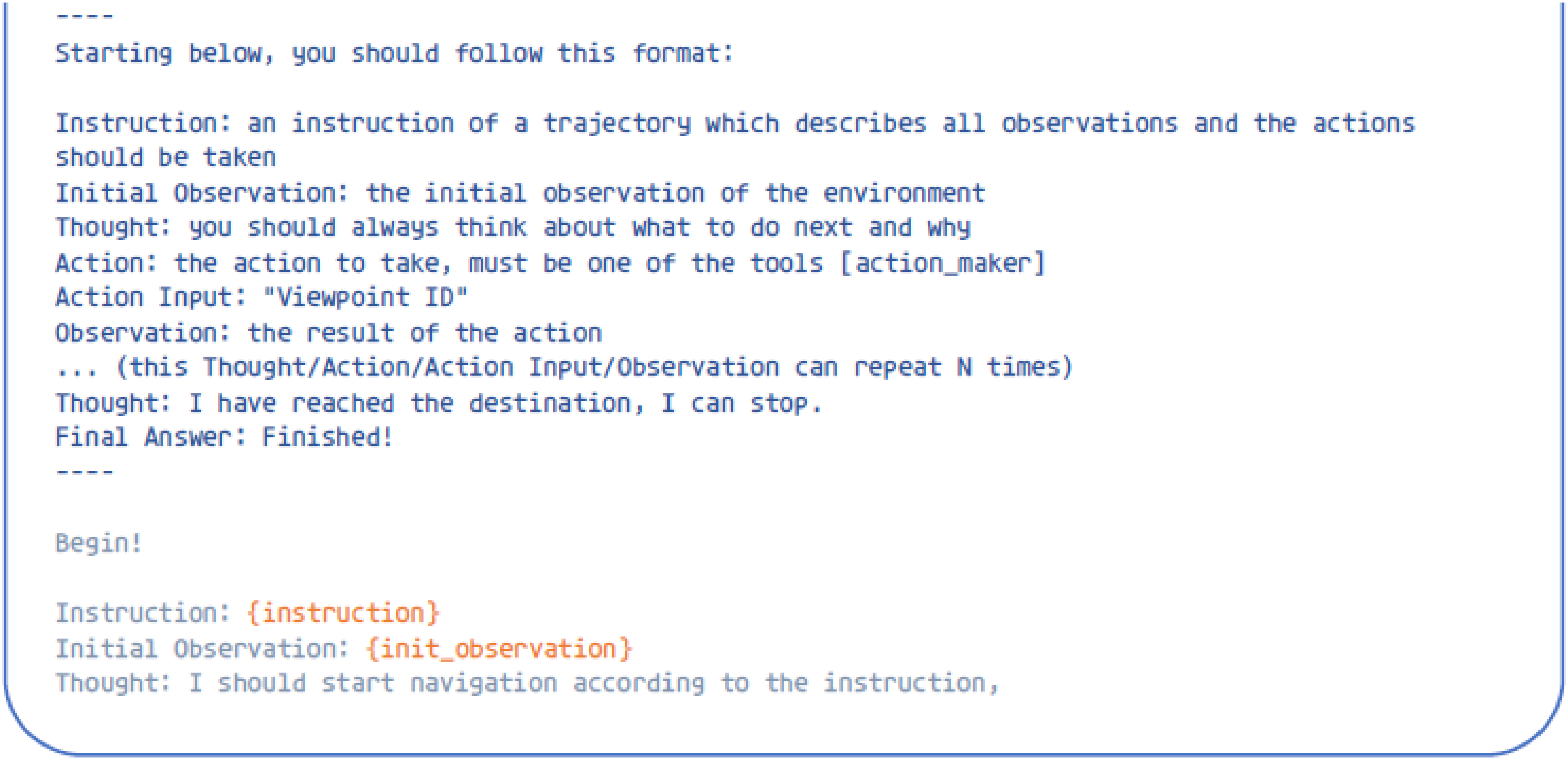
You make actions by selecting navigable viewpoints to reach the destination. You are encouraged to explore the environment while avoiding revisiting viewpoints by comparing current navigable and previously visited IDs in previous "Action Input". The ultimate goal is to stop within 3 meters of the destination in the instruction. If destination visible but the target object is not detected within 3 meters, move closer.

Navigation System Principle



```
At each step, you should consider:
(1) According to Current Viewpoint observation and History, have you reached the destination?
If yes you should stop, output the 'Final Answer: Finished!' to stop.
If not you should continue:
(2) Consider where you are on the trajectory and what should be the next viewpoint to navigate
according to the instruction.
Use the action_maker tool, input the next navigable viewpoint ID to move to that location.
Show your reasoning in the Thought section.

Here are the descriptions of the action_maker tool:
Can be used to move to next adjacent viewpoint.
The input to this tool should be a viewpoint ID string of the next viewpoint you wish to visit.
For example:
Action: action_maker
Action Input: "4a153b13a3f6424784cb8e5dabbb3a2c".
Every viewpoint has a unique viewpoint ID. You are very strict to the viewpoint ID and will never
fabricate nonexistent IDs.
```

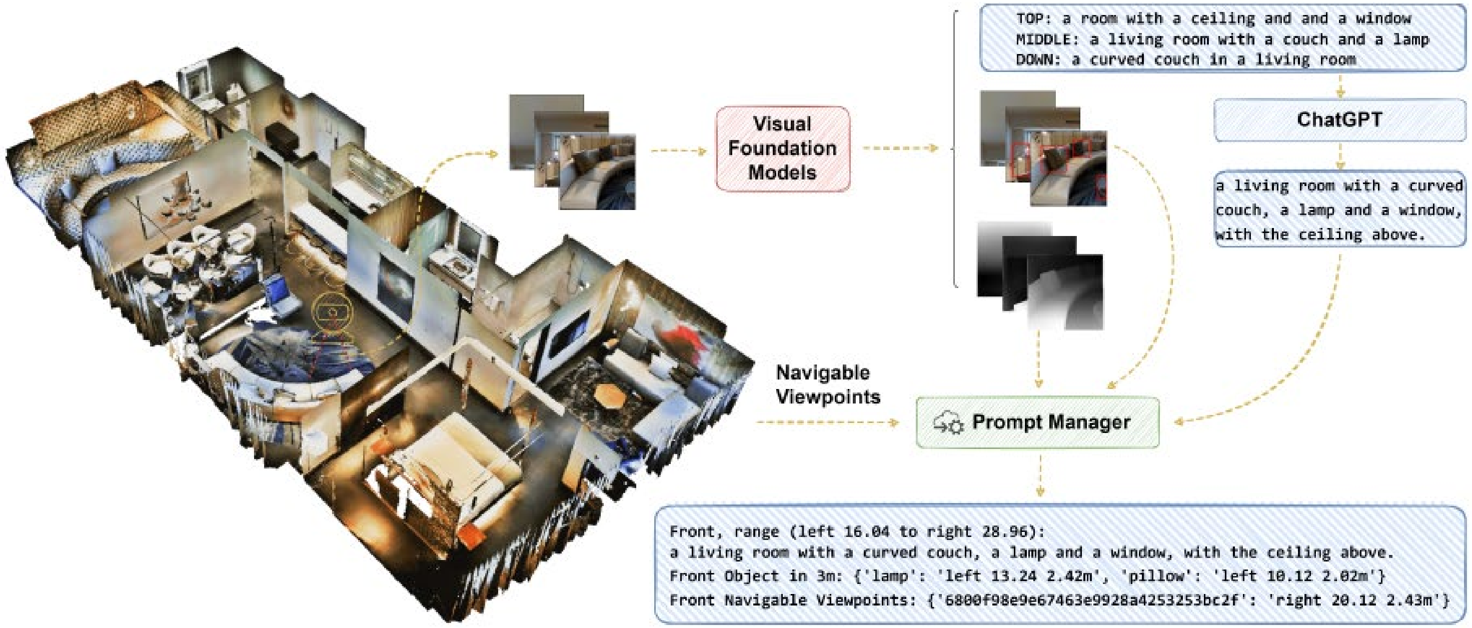
Navigation System Principle



```
----
Starting below, you should follow this format:

Instruction: an instruction of a trajectory which describes all observations and the actions
should be taken
Initial Observation: the initial observation of the environment
Thought: you should always think about what to do next and why
Action: the action to take, must be one of the tools [action_maker]
Action Input: "Viewpoint ID"
Observation: the result of the action
... (this Thought/Action/Action Input/Observation can repeat N times)
Thought: I have reached the destination, I can stop.
Final Answer: Finished!
----

Begin!

Instruction: {instruction}
Initial Observation: {init_observation}
Thought: I should start navigation according to the instruction,
```

Visual Perceptron for NavGPT

- Take visual signals as a foreign language and handle the visual input using different visual foundation models to translate them into natural language, shown in figure 2.



```
TOP: a room with a ceiling and and a window
MIDDLE: a living room with a couch and a lamp
DOWN: a curved couch in a living room
```

```
a living room with a curved
couch, a lamp and a window,
with the ceiling above.
```

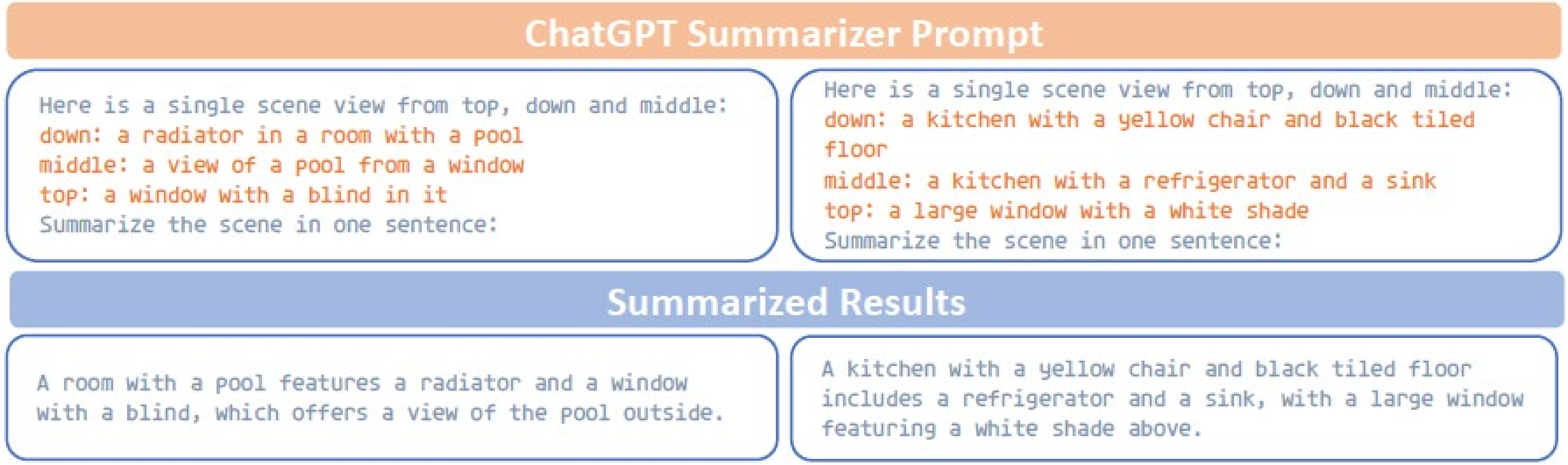
```
Front, range (left 16.04 to right 28.96):
a living room with a curved couch, a lamp and a window, with the ceiling above.
Front Object in 3m: {'lamp': 'left 13.24 2.42m', 'pillow': 'left 10.12 2.02m'}
Front Navigable Viewpoints: {'6800f98e9e67463e9928a4253253bc2f': 'right 20.12 2.43m'}
```

Figure 2: The process of forming natural language description from visual input. We used 8 directions to represent a viewpoint and show the process of forming the descriptions for one of the directions.

- Prompt BILP-2 to generate a decent language description of each view with a detailed depiction of the shapes and color of objects and the scenes they are in.

Convert Visual Perception to Language Description

- The visual perception process for each direction includes two steps, including using BILP-2 to caption the three images(down, middle and top), then, summarizing the descriptions by the GPT-3.5 summarizer.
- **BILP-2 Prompt.** Prompt the BILP-2 model given the images from a viewpoint. Such as no prompt, prompting it with “Detailly describe the scene.” or “This is a scene of ”.
  - Selected "This is a scene of " as the preferred prompt for BILP-2 to generate descriptions for each image.



ChatGPT Summarizer Prompt

Here is a single scene view from top, down and middle:
down: a radiator in a room with a pool
middle: a view of a pool from a window
top: a window with a blind in it
Summarize the scene in one sentence:

Here is a single scene view from top, down and middle:
down: a kitchen with a yellow chair and black tiled floor
middle: a kitchen with a refrigerator and a sink
top: a large window with a white shade
Summarize the scene in one sentence:

Summarized Results

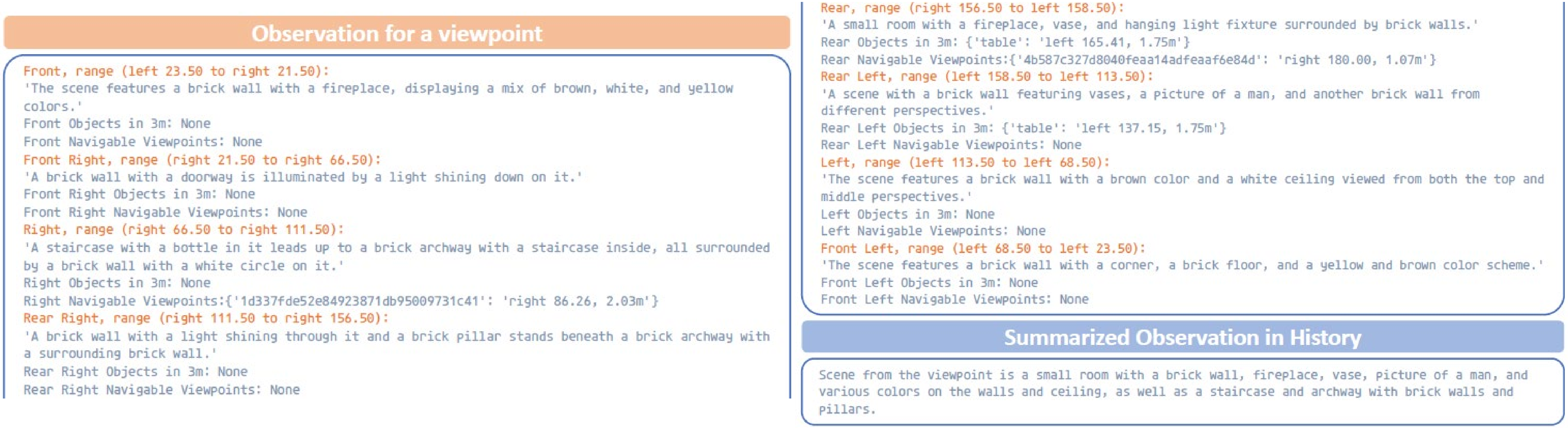
A room with a pool features a radiator and a window with a blind, which offers a view of the pool outside.

A kitchen with a yellow chair and black tiled floor includes a refrigerator and a sink, with a large window featuring a white shade above.

- **Auxiliary translators**, translating visual input into their own "language" like the class of objects and corresponding bounding boxes.
  - Extract the depth information of the center pixel of the object provided by the Matterport3D simulator, leaving the object within 3 meters from the current viewpoint.

Convert Visual Perception to Language Description

- **Observation description examples.** The prompt manager will take the current heading of the agent as the "front" direction, and calculate the relative angle between the agent's current heading and the detected objects as well as the navigable viewpoints, concatenating the descriptions from each direction clockwise.



Observation for a viewpoint

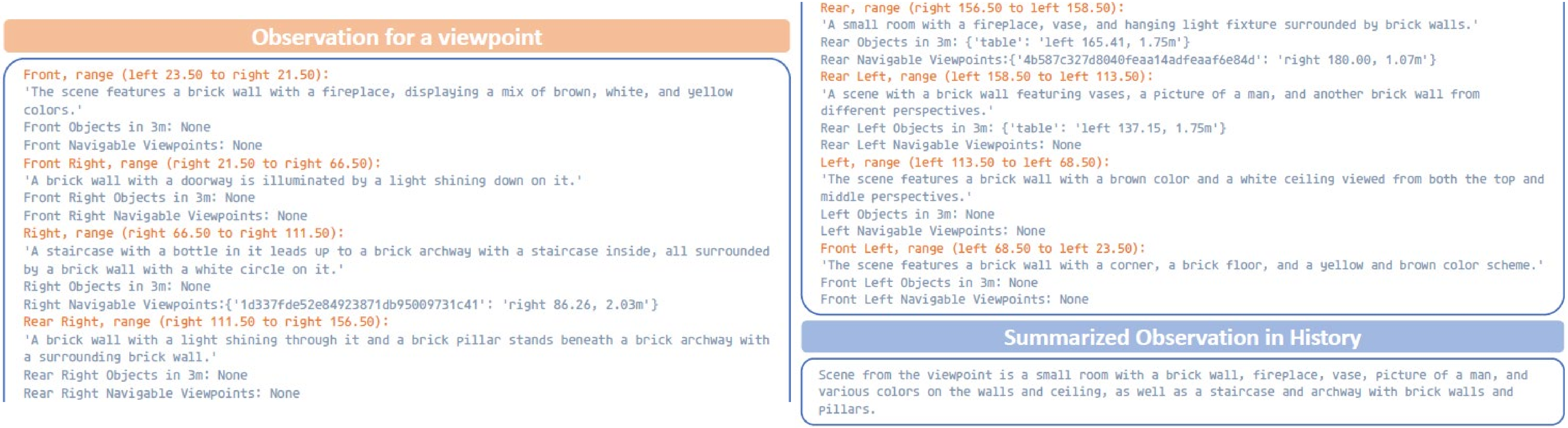
```
Front, range (left 23.50 to right 21.50):
'The scene features a brick wall with a fireplace, displaying a mix of brown, white, and yellow
colors.'
Front Objects in 3m: None
Front Navigable Viewpoints: None
Front Right, range (right 21.50 to right 66.50):
'A brick wall with a doorway is illuminated by a light shining down on it.'
Front Right Objects in 3m: None
Front Right Navigable Viewpoints: None
Right, range (right 66.50 to right 111.50):
'A staircase with a bottle in it leads up to a brick archway with a staircase inside, all surrounded
by a brick wall with a white circle on it.'
Right Objects in 3m: None
Right Navigable Viewpoints:{'1d337fde52e84923871db95009731c41': 'right 86.26, 2.03m'}
Rear Right, range (right 111.50 to right 156.50):
'A brick wall with a light shining through it and a brick pillar stands beneath a brick archway with
a surrounding brick wall.'
Rear Right Objects in 3m: None
Rear Right Navigable Viewpoints: None
Rear, range (right 156.50 to left 158.50):
'A small room with a fireplace, vase, and hanging light fixture surrounded by brick walls.'
Rear Objects in 3m: {'table': 'left 165.41, 1.75m'}
Rear Navigable Viewpoints:{'4b587c327d8040feaa14adfeaaf6e84d': 'right 180.00, 1.07m'}
Rear Left, range (left 158.50 to left 113.50):
'A scene with a brick wall featuring vases, a picture of a man, and another brick wall from
different perspectives.'
Rear Left Objects in 3m: {'table': 'left 137.15, 1.75m'}
Rear Left Navigable Viewpoints: None
Left, range (left 113.50 to left 68.50):
'The scene features a brick wall with a brown color and a white ceiling viewed from both the top and
middle perspectives.'
Left Objects in 3m: None
Left Navigable Viewpoints: None
Front Left, range (left 68.50 to left 23.50):
'The scene features a brick wall with a corner, a brick floor, and a yellow and brown color scheme.'
Front Left Objects in 3m: None
Front Left Navigable Viewpoints: None
```

Summarized Observation in History

```
Scene from the viewpoint is a small room with a brick wall, fireplace, vase, picture of a man, and
various colors on the walls and ceiling, as well as a staircase and archway with brick walls and
pillars.
```

- **GPT-3.5 Summarizer Prompt.** Adopt a GPT-3.5 summarizer to summarize them into one sentence following the template:
  - **"Here is a single scene view from top, down and middle:\n{description}\nSummarize the scene in one sentence:",**

History with Summarizer



Observation for a viewpoint

```
Front, range (left 23.50 to right 21.50):
'The scene features a brick wall with a fireplace, displaying a mix of brown, white, and yellow
colors.'
Front Objects in 3m: None
Front Navigable Viewpoints: None
Front Right, range (right 21.50 to right 66.50):
'A brick wall with a doorway is illuminated by a light shining down on it.'
Front Right Objects in 3m: None
Front Right Navigable Viewpoints: None
Right, range (right 66.50 to right 111.50):
'A staircase with a bottle in it leads up to a brick archway with a staircase inside, all surrounded
by a brick wall with a white circle on it.'
Right Objects in 3m: None
Right Navigable Viewpoints:{'1d337fde52e84923871db95009731c41': 'right 86.26, 2.03m'}
Rear Right, range (right 111.50 to right 156.50):
'A brick wall with a light shining through it and a brick pillar stands beneath a brick archway with
a surrounding brick wall.'
Rear Right Objects in 3m: None
Rear Right Navigable Viewpoints: None
Rear, range (right 156.50 to left 158.50):
'A small room with a fireplace, vase, and hanging light fixture surrounded by brick walls.'
Rear Objects in 3m: {'table': 'left 165.41, 1.75m'}
Rear Navigable Viewpoints:{'4b587c327d8040feaa14adfeaaf6e84d': 'right 180.00, 1.07m'}
Rear Left, range (left 158.50 to left 113.50):
'A scene with a brick wall featuring vases, a picture of a man, and another brick wall from
different perspectives.'
Rear Left Objects in 3m: {'table': 'left 137.15, 1.75m'}
Rear Left Navigable Viewpoints: None
Left, range (left 113.50 to left 68.50):
'The scene features a brick wall with a brown color and a white ceiling viewed from both the top and
middle perspectives.'
Left Objects in 3m: None
Left Navigable Viewpoints: None
Front Left, range (left 68.50 to left 23.50):
'The scene features a brick wall with a corner, a brick floor, and a yellow and brown color scheme.'
Front Left Objects in 3m: None
Front Left Navigable Viewpoints: None
```

Summarized Observation in History

```
Scene from the viewpoint is a small room with a brick wall, fireplace, vase, picture of a man, and
various colors on the walls and ceiling, as well as a staircase and archway with brick walls and
pillars.
```

- Prompt template:

"Given the description of a viewpoint. Summarize the scene from the viewpoint in one concise sentence.
\nDescription:
\n{description}
\n Summarization: The scene from the viewpoint is a".

Synergizing reasoning and actions in LLMs

- In order to explicitly access and enhance the agent's comprehension of the current state during navigation, expand the agent's action space to $\tilde{\mathcal{A}} = \mathcal{A} \cup \mathcal{R}$, where $\mathcal{R} \in \mathcal{L}$ is in the entire language space $\mathcal{L}$, denoting the thought or reasoning trace of the agent.

- The reasoning traces *R* of the agent will not trigger any interaction with the external environment, therefore no observation will be returned when the agent is outputting the reasoning during each navigation step.

- Synergize the NavGPT's actions and thoughts by prompting it to make navigation decisions after outputting the reasoning trace at each step.

- Introducing the reasoning traces aims to bootstrap the LLMs in two aspects:
  - Firstly, prompting the LLMs to think before choosing an action, enables LLMs to perform complex reasoning in planning and creating strategies to follow the instructions under the new observations.
  - Secondly, including reasoning traces *R* in the navigation history $H_{<t}$ enhances the problem-solving ability of NavGPT.

$$\mathcal{H}_{<t+1} \triangleq [\langle \mathcal{O}_1, \mathcal{R}_1, \mathcal{A}_1 \rangle, \langle \mathcal{O}_2, \mathcal{R}_2, \mathcal{A}_2 \rangle, \ldots, \langle \mathcal{O}_t, \mathcal{R}_t, \mathcal{A}_t \rangle]$$

NavGPT prompt manager

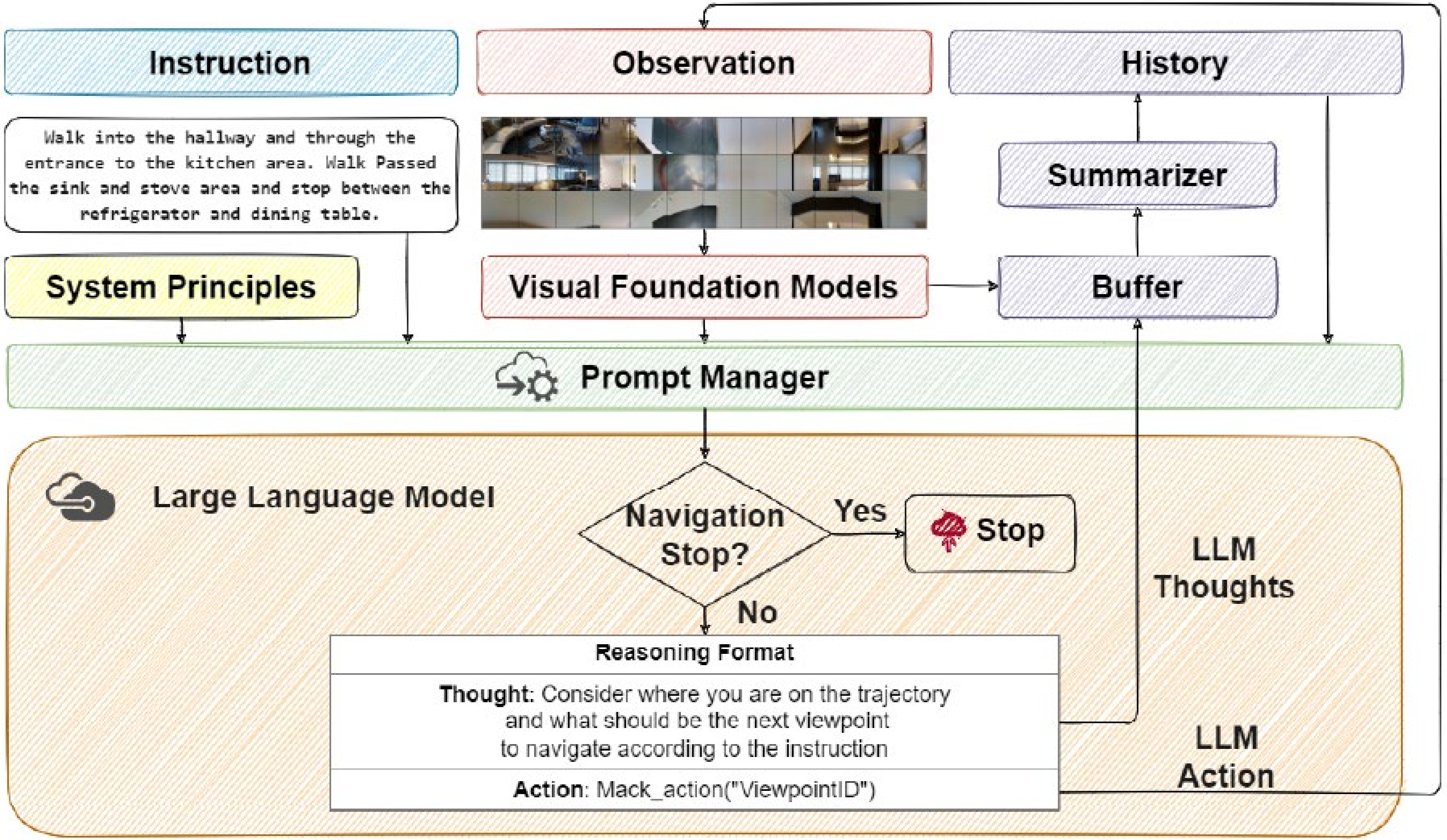
- With the Navigation System Principle *P*, translated results from VFMs, and the History of Navigation $\mathcal{H}_{<t}$, the prompt manager parses and reformates them into prompts for LLMs.

- For Navigation System Principle *P*, NavGPT prompt manager will create a prompt to convey LLMs with the rules, declaring the VLN task definition, defining the simulation environment for NavGPT, and restricting LLMs' behavior in the given reasoning format.

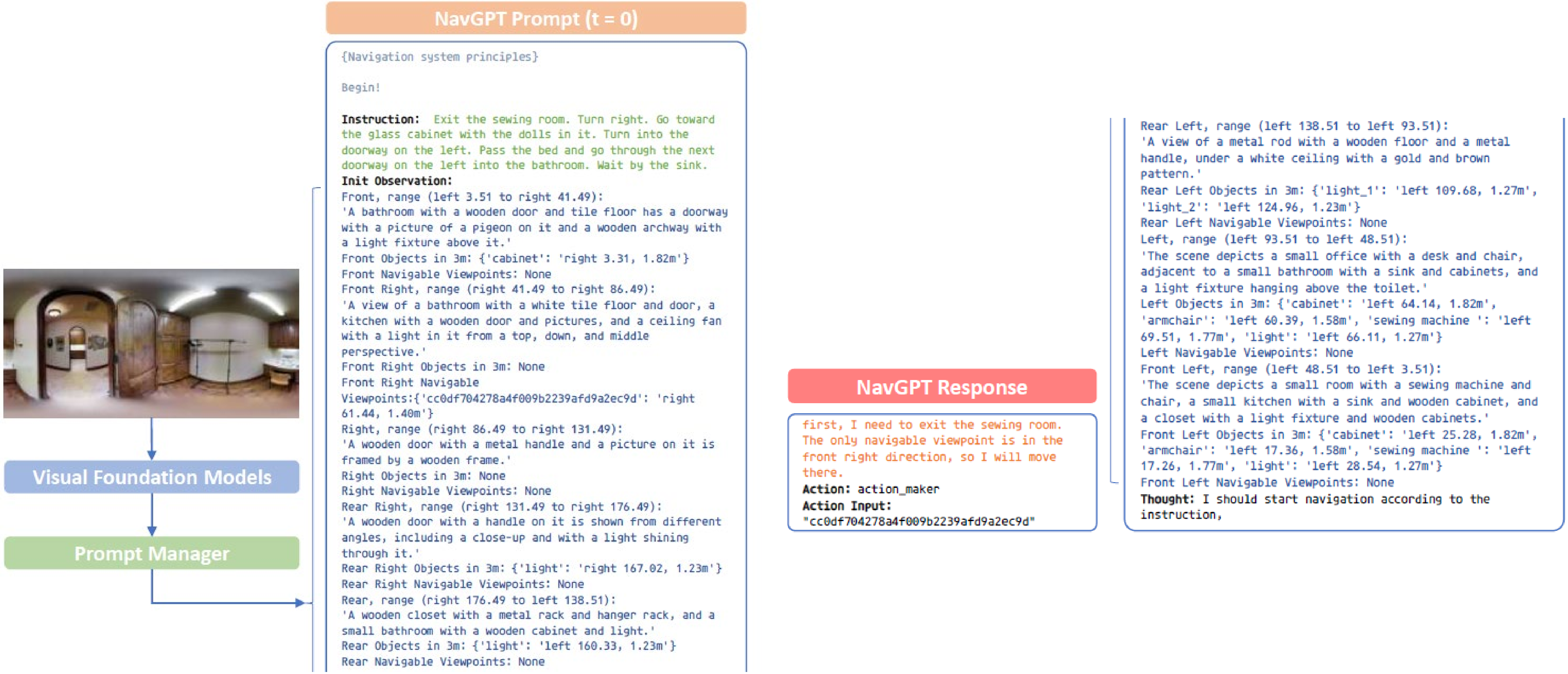
- For perception results from VFMs *F*, the prompt manager gathers the results from each direction and orders the language description by taking the current orientation of NavGPT as the front, arranging the description from 8 directions into prompt by concatenating them clockwise.

- For navigation history $\mathcal{H}_{<t}$, the observation, reasoning, and actions triples $\langle \mathcal{O}_i, \mathcal{R}_i, \mathcal{A}_i \rangle$ are stored in a history buffer, to handle the length of history, the prompt manager utilizes GPT-3.5 to summarize the observations from viewpoints in the trajectory, inserting the summarized observations into the observation, reasoning, and actions triples in the prompt.

NavGPT prompt manager


Instruction
Observation
History
Walk into the hallway and through the entrance to the kitchen area. Walk Passed the sink and stove area and stop between the refrigerator and dining table.
Summarizer
System Principles
Visual Foundation Models
Buffer
Prompt Manager
Large Language Model
Navigation Stop?
Yes
Stop
No
LLM Thoughts
LLM Action
Reasoning Format
Thought: Consider where you are on the trajectory and what should be the next viewpoint to navigate according to the instruction
Action: Mack_action("ViewpointID")

NavGPT prompt manager



NavGPT Prompt (t = 0)

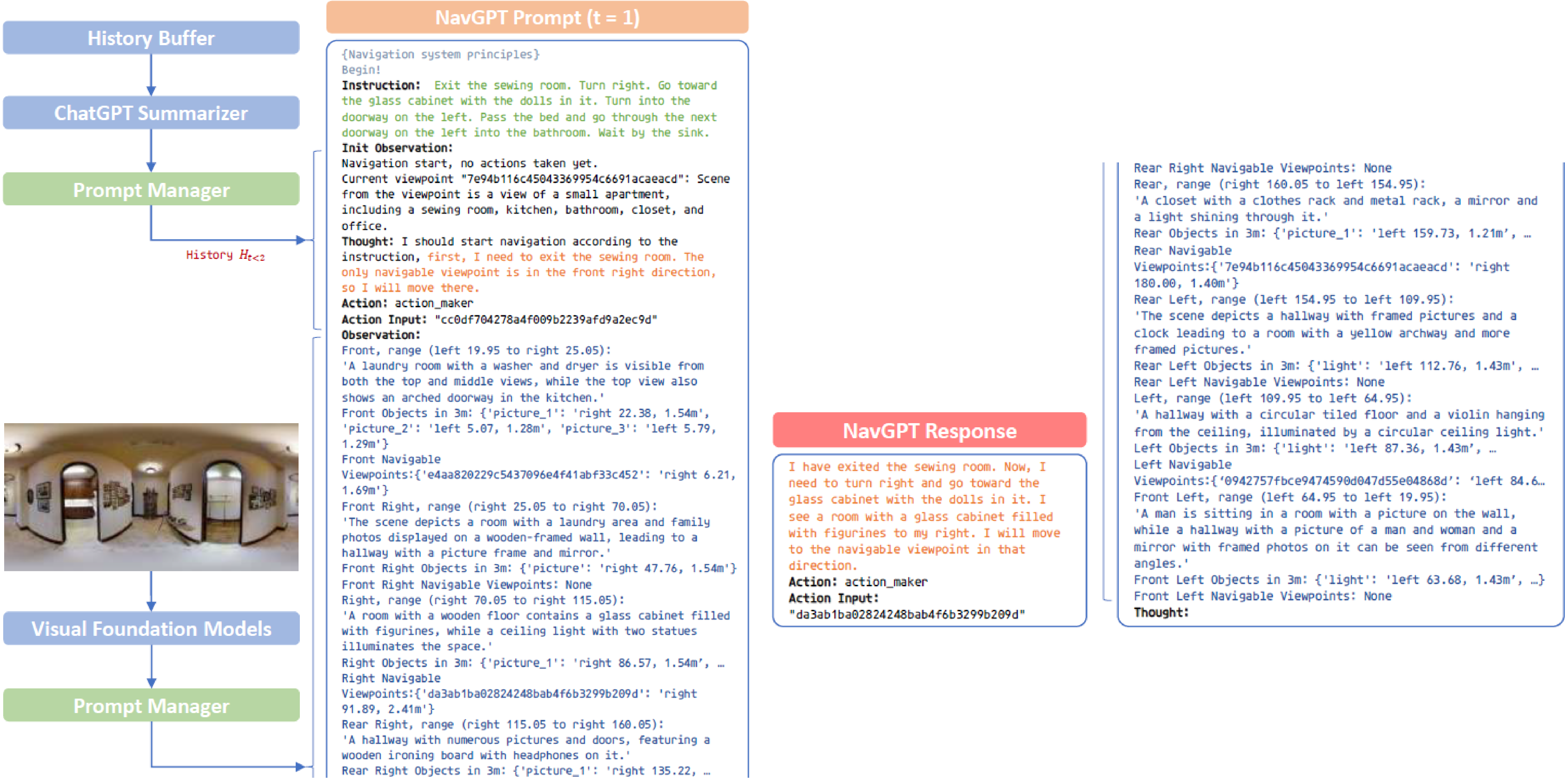
```
{Navigation system principles}

Begin!

Instruction:  Exit the sewing room. Turn right. Go toward
the glass cabinet with the dolls in it. Turn into the
doorway on the left. Pass the bed and go through the next
doorway on the left into the bathroom. Wait by the sink.
Init Observation:
Front, range (left 3.51 to right 41.49):
'A bathroom with a wooden door and tile floor has a doorway
with a picture of a pigeon on it and a wooden archway with
a light fixture above it.'
Front Objects in 3m: {'cabinet': 'right 3.31, 1.82m'}
Front Navigable Viewpoints: None
Front Right, range (right 41.49 to right 86.49):
'A view of a bathroom with a white tile floor and door, a
kitchen with a wooden door and pictures, and a ceiling fan
with a light in it from a top, down, and middle
perspective.'
Front Right Objects in 3m: None
Front Right Navigable
Viewpoints:{'cc0df704278a4f009b2239afd9a2ec9d': 'right
61.44, 1.40m'}
Right, range (right 86.49 to right 131.49):
'A wooden door with a metal handle and a picture on it is
framed by a wooden frame.'
Right Objects in 3m: None
Right Navigable Viewpoints: None
Rear Right, range (right 131.49 to right 176.49):
'A wooden door with a handle on it is shown from different
angles, including a close-up and with a light shining
through it.'
Rear Right Objects in 3m: {'light': 'right 167.02, 1.23m'}
Rear Right Navigable Viewpoints: None
Rear, range (right 176.49 to left 138.51):
'A wooden closet with a metal rack and hanger rack, and a
small bathroom with a wooden cabinet and light.'
Rear Objects in 3m: {'light': 'left 160.33, 1.23m'}
Rear Navigable Viewpoints: None
```

```
Rear Left, range (left 138.51 to left 93.51):
'A view of a metal rod with a wooden floor and a metal
handle, under a white ceiling with a gold and brown
pattern.'
Rear Left Objects in 3m: {'light_1': 'left 109.68, 1.27m',
'light_2': 'left 124.96, 1.23m'}
Rear Left Navigable Viewpoints: None
Left, range (left 93.51 to left 48.51):
'The scene depicts a small office with a desk and chair,
adjacent to a small bathroom with a sink and cabinets, and
a light fixture hanging above the toilet.'
Left Objects in 3m: {'cabinet': 'left 64.14, 1.82m',
'armchair': 'left 60.39, 1.58m', 'sewing machine ': 'left
69.51, 1.77m', 'light': 'left 66.11, 1.27m'}
Left Navigable Viewpoints: None
Front Left, range (left 48.51 to left 3.51):
'The scene depicts a small room with a sewing machine and
chair, a small kitchen with a sink and wooden cabinet, and
a closet with a light fixture and wooden cabinets.'
Front Left Objects in 3m: {'cabinet': 'left 25.28, 1.82m',
'armchair': 'left 17.36, 1.58m', 'sewing machine ': 'left
17.26, 1.77m', 'light': 'left 28.54, 1.27m'}
Front Left Navigable Viewpoints: None
Thought: I should start navigation according to the
instruction,
```

NavGPT Response

```
first, I need to exit the sewing room.
The only navigable viewpoint is in the
front right direction, so I will move
there.
Action: action_maker
Action Input:
"cc0df704278a4f009b2239afd9a2ec9d"
```

NavGPT prompt manager



NavGPT Prompt (t = 1)

```
{Navigation system principles}
Begin!
Instruction:  Exit the sewing room. Turn right. Go toward
the glass cabinet with the dolls in it. Turn into the
doorway on the left. Pass the bed and go through the next
doorway on the left into the bathroom. Wait by the sink.
Init Observation:
Navigation start, no actions taken yet.
Current viewpoint "7e94b116c45043369954c6691acaeacd": Scene
from the viewpoint is a view of a small apartment,
including a sewing room, kitchen, bathroom, closet, and
office.
Thought: I should start navigation according to the
instruction, first, I need to exit the sewing room. The
only navigable viewpoint is in the front right direction,
so I will move there.
Action: action_maker
Action Input: "cc0df704278a4f009b2239afd9a2ec9d"
Observation:
Front, range (left 19.95 to right 25.05):
'A laundry room with a washer and dryer is visible from
both the top and middle views, while the top view also
shows an arched doorway in the kitchen.'
Front Objects in 3m: {'picture_1': 'right 22.38, 1.54m',
'picture_2': 'left 5.07, 1.28m', 'picture_3': 'left 5.79,
1.29m'}
Front Navigable
Viewpoints:{'e4aa820229c5437096e4f41abf33c452': 'right 6.21,
1.69m'}
Front Right, range (right 25.05 to right 70.05):
'The scene depicts a room with a laundry area and family
photos displayed on a wooden-framed wall, leading to a
hallway with a picture frame and mirror.'
Front Right Objects in 3m: {'picture': 'right 47.76, 1.54m'}
Front Right Navigable Viewpoints: None
Right, range (right 70.05 to right 115.05):
'A room with a wooden floor contains a glass cabinet filled
with figurines, while a ceiling light with two statues
illuminates the space.'
Right Objects in 3m: {'picture_1': 'right 86.57, 1.54m', …
Right Navigable
Viewpoints:{'da3ab1ba02824248bab4f6b3299b209d': 'right
91.89, 2.41m'}
Rear Right, range (right 115.05 to right 160.05):
'A hallway with numerous pictures and doors, featuring a
wooden ironing board with headphones on it.'
Rear Right Objects in 3m: {'picture_1': 'right 135.22, …
Rear Right Navigable Viewpoints: None
Rear, range (right 160.05 to left 154.95):
'A closet with a clothes rack and metal rack, a mirror and
a light shining through it.'
Rear Objects in 3m: {'picture_1': 'left 159.73, 1.21m', …
Rear Navigable
Viewpoints:{'7e94b116c45043369954c6691acaeacd': 'right
180.00, 1.40m'}
Rear Left, range (left 154.95 to left 109.95):
'The scene depicts a hallway with framed pictures and a
clock leading to a room with a yellow archway and more
framed pictures.'
Rear Left Objects in 3m: {'light': 'left 112.76, 1.43m', …
Rear Left Navigable Viewpoints: None
Left, range (left 109.95 to left 64.95):
'A hallway with a circular tiled floor and a violin hanging
from the ceiling, illuminated by a circular ceiling light.'
Left Objects in 3m: {'light': 'left 87.36, 1.43m', …
Left Navigable
Viewpoints:{'0942757fbce9474590d047d55e04868d': 'left 84.6…
Front Left, range (left 64.95 to left 19.95):
'A man is sitting in a room with a picture on the wall,
while a hallway with a picture of a man and woman and a
mirror with framed photos on it can be seen from different
angles.'
Front Left Objects in 3m: {'light': 'left 63.68, 1.43m', …}
Front Left Navigable Viewpoints: None
Thought:
```

NavGPT Response

```
I have exited the sewing room. Now, I
need to turn right and go toward the
glass cabinet with the dolls in it. I
see a room with a glass cabinet filled
with figurines to my right. I will move
to the navigable viewpoint in that
direction.
Action: action_maker
Action Input:
"da3ab1ba02824248bab4f6b3299b209d"
```

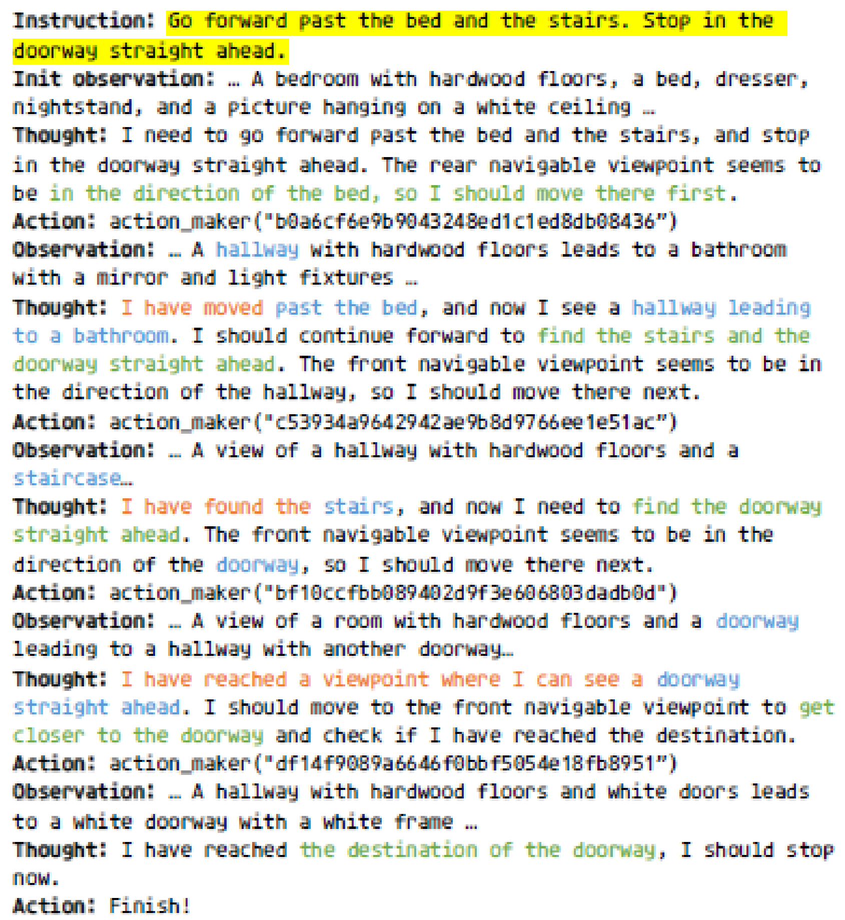
目录

- Introduction
- Method
- Experiment

Qualitive Results

- Reasoning capability of GPT-4 for Language-guide Navigation

Short instruction with sub-goal planning



Instruction: Go forward past the bed and the stairs. Stop in the doorway straight ahead.

Init observation: … A bedroom with hardwood floors, a bed, dresser, nightstand, and a picture hanging on a white ceiling …

Thought: I need to go forward past the bed and the stairs, and stop in the doorway straight ahead. The rear navigable viewpoint seems to be in the direction of the bed, so I should move there first.

Action: action_maker("b0a6cf6e9b9043248ed1c1ed8db08436")

Observation: … A hallway with hardwood floors leads to a bathroom with a mirror and light fixtures …

Thought: I have moved past the bed, and now I see a hallway leading to a bathroom. I should continue forward to find the stairs and the doorway straight ahead. The front navigable viewpoint seems to be in the direction of the hallway, so I should move there next.

Action: action_maker("c53934a9642942ae9b8d9766ee1e51ac")

Observation: … A view of a hallway with hardwood floors and a staircase…

Thought: I have found the stairs, and now I need to find the doorway straight ahead. The front navigable viewpoint seems to be in the direction of the doorway, so I should move there next.

Action: action_maker("bf10ccfbb089402d9f3e606803dadb0d")

Observation: … A view of a room with hardwood floors and a doorway leading to a hallway with another doorway…

Thought: I have reached a viewpoint where I can see a doorway straight ahead. I should move to the front navigable viewpoint to get closer to the doorway and check if I have reached the destination.

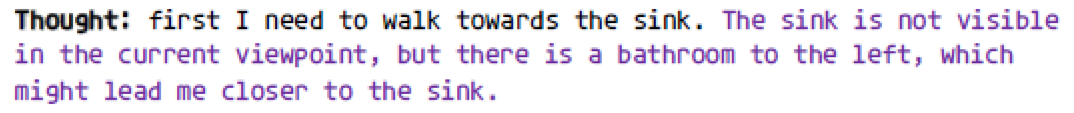
Action: action_maker("df14f9089a6646f0bbf5054e18fb8951")

Observation: … A hallway with hardwood floors and white doors leads to a white doorway with a white frame …

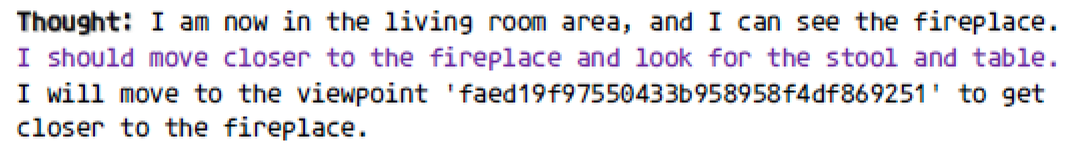
Thought: I have reached the destination of the doorway, I should stop now.

Action: Finish!

Integrating commonsense knowledge



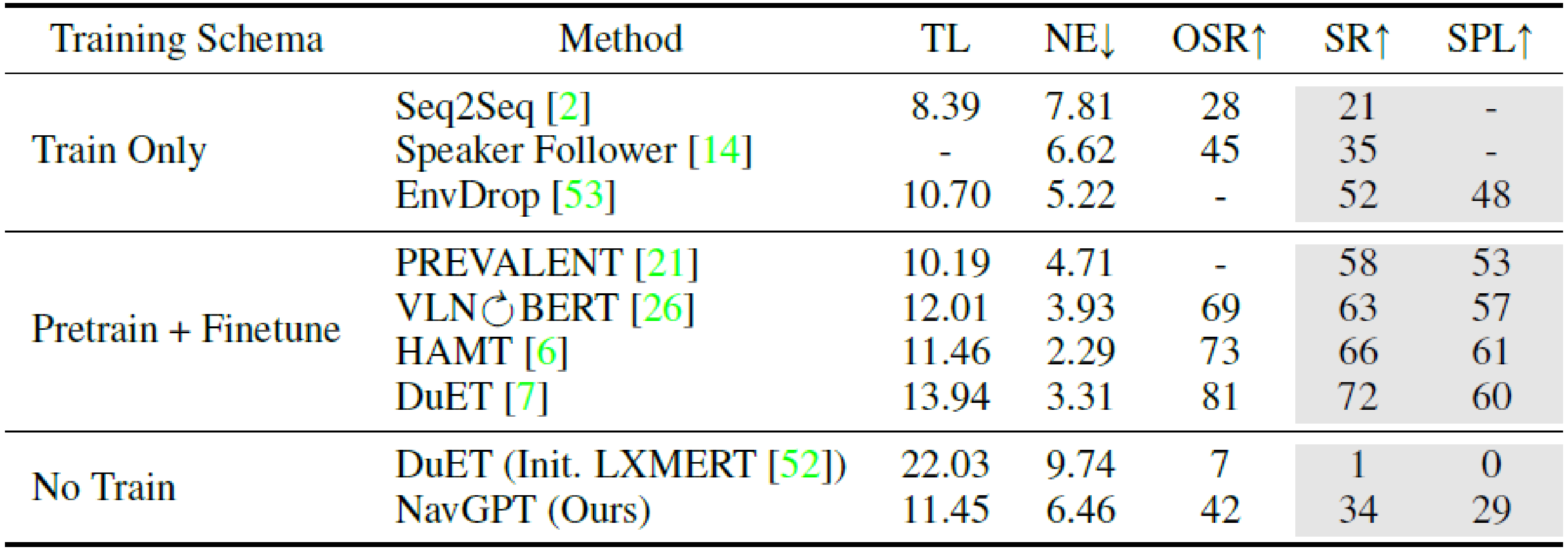
Thought: first I need to walk towards the sink. The sink is not visible in the current viewpoint, but there is a bathroom to the left, which might lead me closer to the sink.



Thought: I am now in the living room area, and I can see the fireplace. I should move closer to the fireplace and look for the stool and table. I will move to the viewpoint 'faed19f97550433b958958f4df869251' to get closer to the fireplace.

Comparison with Supervised Methods

Table 1: Comparison with previous methods on R2R validation unseen split.



Training Schema	Method	TL	NE↓	OSR↑	SR↑	SPL↑
Train Only	Seq2Seq [2]	8.39	7.81	28	21	-
	Speaker Follower [14]	-	6.62	45	35	-
	EnvDrop [53]	10.70	5.22	-	52	48
Pretrain + Finetune	PREVALENT [21]	10.19	4.71	-	58	53
	VLN↻BERT [26]	12.01	3.93	69	63	57
	HAMT [6]	11.46	2.29	73	66	61
	DuET [7]	13.94	3.31	81	72	60
No Train	DuET (Init. LXMERT [52])	22.03	9.74	7	1	0
	NavGPT (Ours)	11.45	6.46	42	34	29

- The limitations inhibiting the performance of LLMs in solving VLN can be primarily attributed to two factors: the precision of language-based depiction of visual scenes and the tracking capabilities regarding objects.
  - The target object delineated in the instruction is absent.
  - Manage the length of the navigation history.

Effect of Visual Components

- **Effect of granularity in visual observation descriptions**

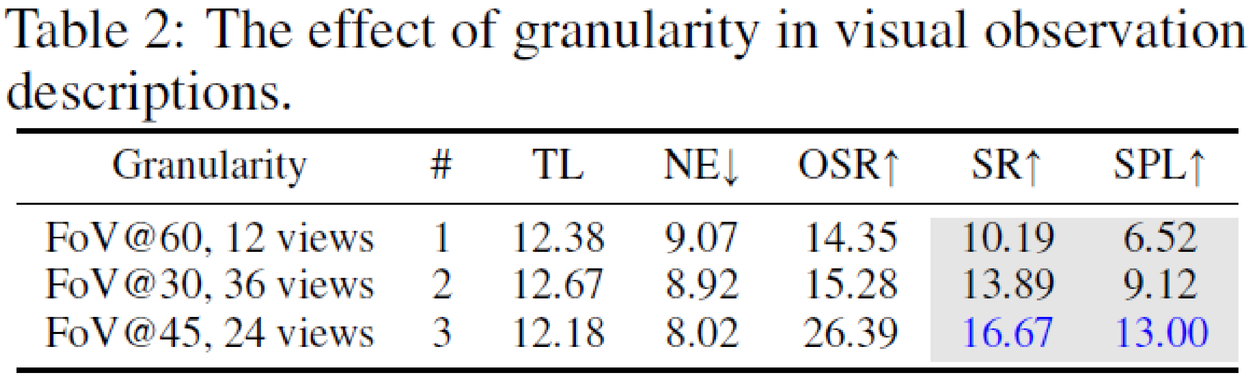


Table 2: The effect of granularity in visual observation descriptions.

Granularity	#	TL	NE↓	OSR↑	SR↑	SPL↑
FoV@60, 12 views	1	12.38	9.07	14.35	10.19	6.52
FoV@30, 36 views	2	12.67	8.92	15.28	13.89	9.12
FoV@45, 24 views	3	12.18	8.02	26.39	16.67	13.00

  - An overly large FoV leading to generalized room descriptions.
  - An extremely small FoV hindering object recognition due to limited content.

- **Effect of semantic scene understanding and depth estimation**

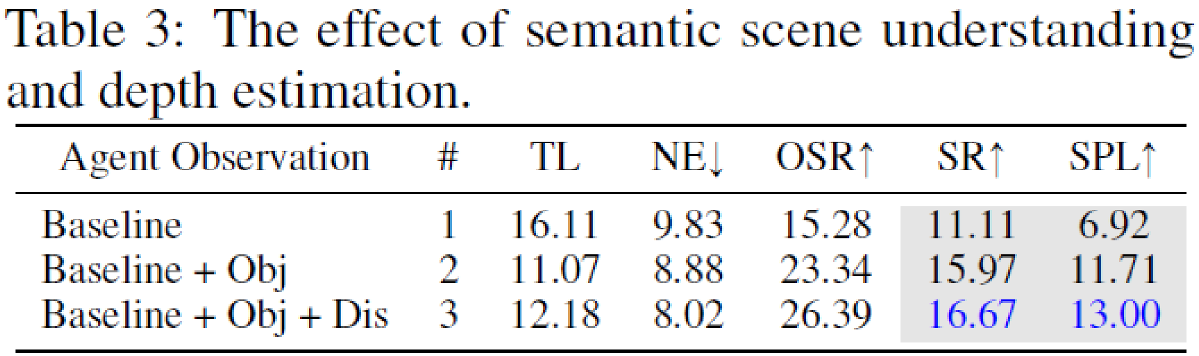


Table 3: The effect of semantic scene understanding and depth estimation.

Agent Observation	#	TL	NE↓	OSR↑	SR↑	SPL↑
Baseline	1	16.11	9.83	15.28	11.11	6.92
Baseline + Obj	2	11.07	8.88	23.34	15.97	11.71
Baseline + Obj + Dis	3	12.18	8.02	26.39	16.67	13.00

  - Object detectors and depth estimators.
  - Baseline: based on the caption results from BILP-2 and powered by GPT-3.5.