Design and Development of a Human-Agent Collaboration Model for Situation Awareness in Cockpit

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1. Background

1 **The Challenges of Full Autonomous Driving**

Level 5 autonomous driving still faces challenges from technology, legal issues, and ethics[1]. Thus, OEMs are adopting L2 and L3 autonomous features (ADAS).

2 **Human-Centered Driving**

For the foreseeable future, humans will remain at the core of driving. Human-Centered Driving aims to enhance the driving experience and safety for humans.

3 **Human-Agent Collaboration**

Designing effective collaboration mechanisms between human drivers and ADASs is crucial for Human-Centered Driving.

1.1 Challenges and Requirements

Advanced Driver Assistance Systems (ADASs) may intermittently **require human re-engagement** in vehicle operation. Conversely, **drivers may need the support** of ADASs in certain scenarios[1]...Understanding and predicting the **human driver's intentions** is critical to this two-way cooperative process[2].

Establishing an **efficient, transparent communication mechanism** between ADASs and human drivers to ensure rapid and accurate information exchange at critical moments is a significant challenge[3]...

How to process and **integrate information from various sensors and data sources** to achieve accurate **situation awareness** is a key issue in system design[4]...

Excerpt from the Literature Review and Requirements Analysis of this project.

1.2 Motivation

Design and develop a **Human-Agent**[1] **Collaboration** model considering

1. **human driver's intention**
2. **communication mechanism**

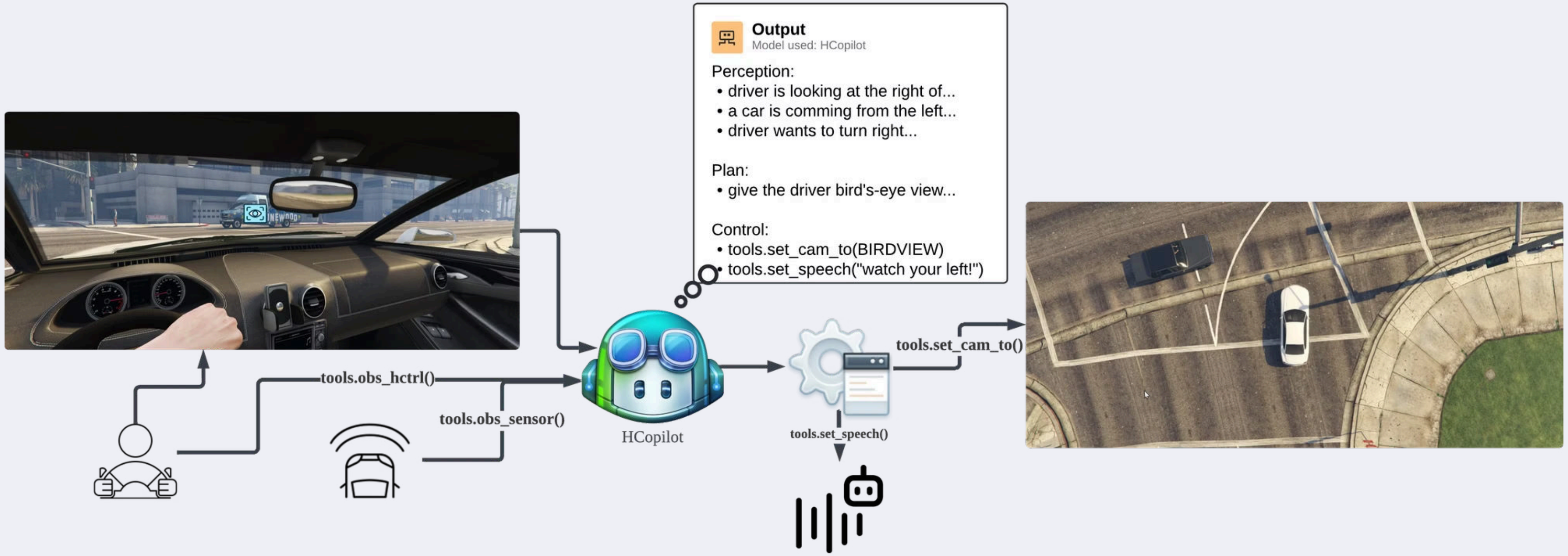
to improve **human-centered driving** in:

User Experience (UX)	Security
Intention-Based Implicit Interaction	Low Attention Alerts
Driver Situation Awareness Enhancement	Potential Threat Alerts
ADAS[2] *Preferences Suggestion*	*Autonomous Emergency Takeover*

Excerpt from the Software Feature List of this project.

2. My Solution:

HCockpit and HCopilot



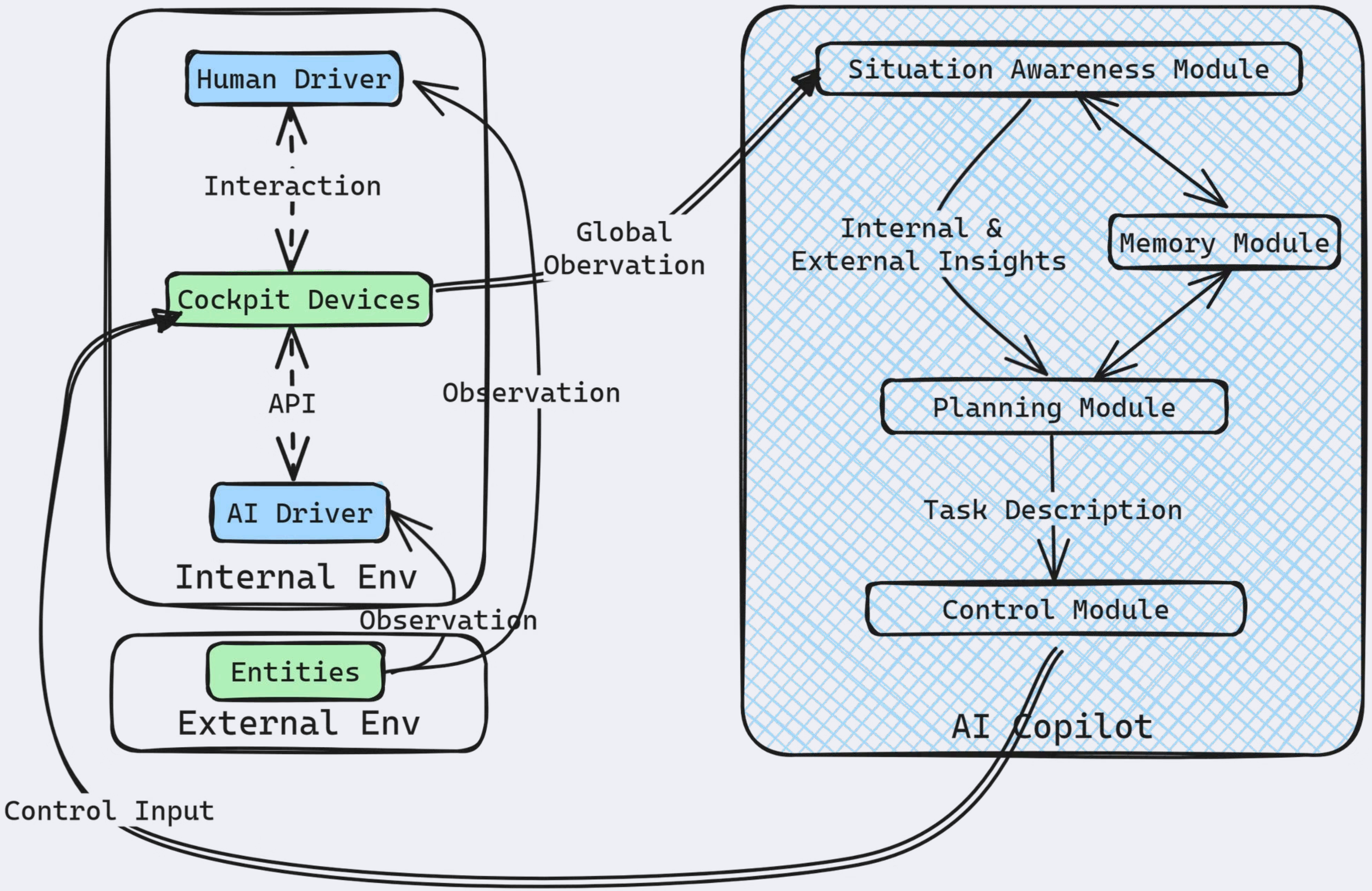
3. Design and Implementation

1 **HCockpit Architecture**

2 **HCopilot Implementation**

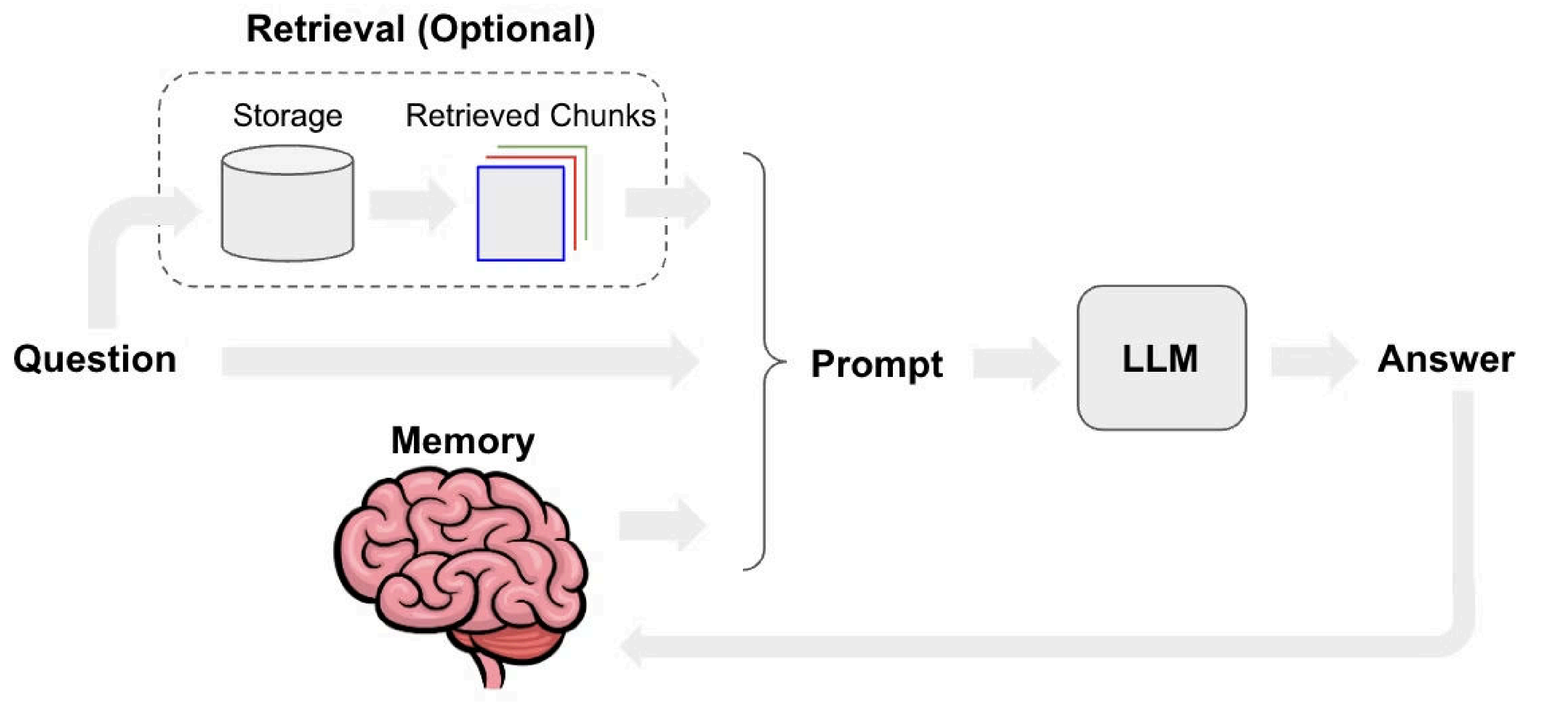
HCopilot is an agent developed following HCockpit architecture.

3.1 HCockpit Architecture

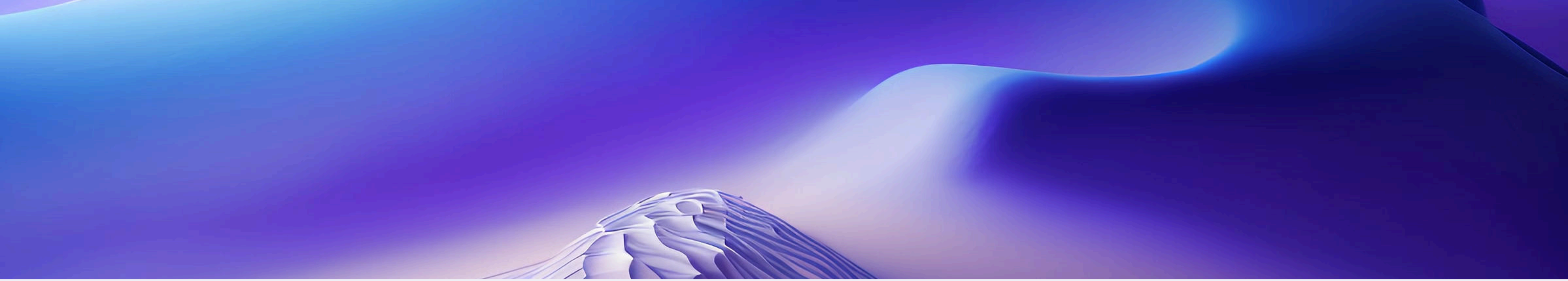


Design Basis: The Rise and Potential of Large Language Model Based Agents: A Survey[1]

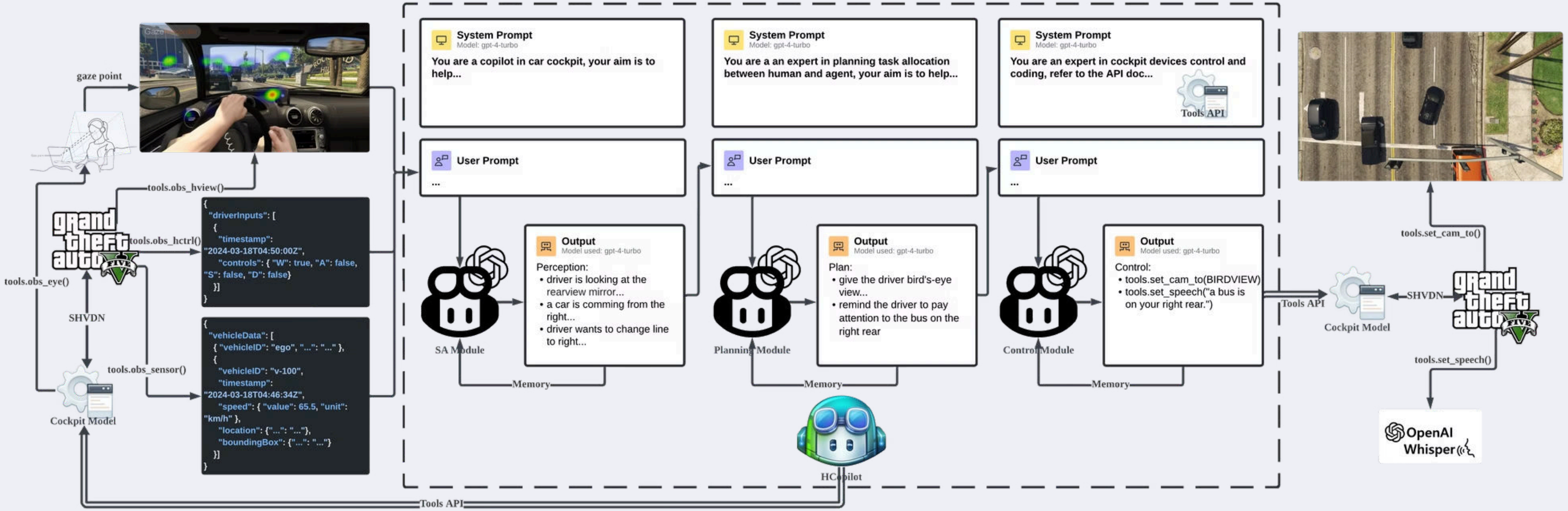
3.1.1 Context Awareness



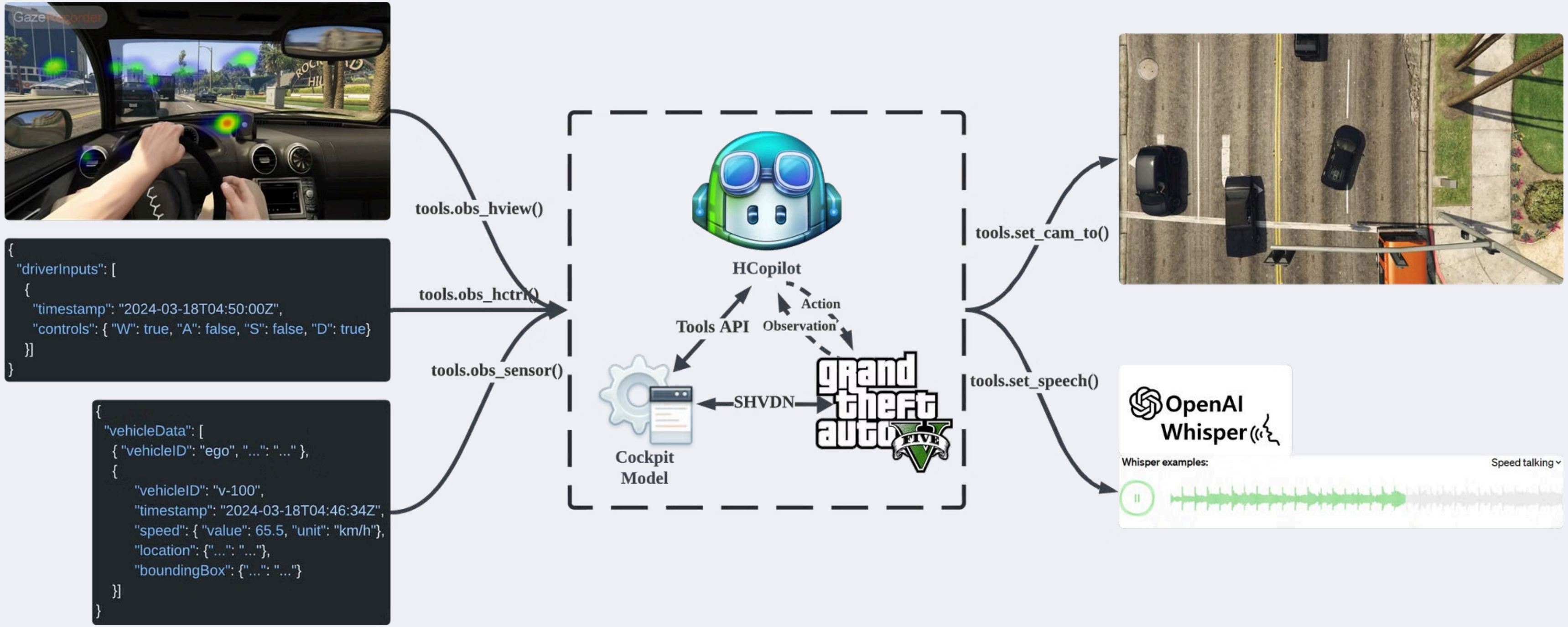
Inspired by ChatGPT[1] architecture.



3.2 HCopilot Implementation

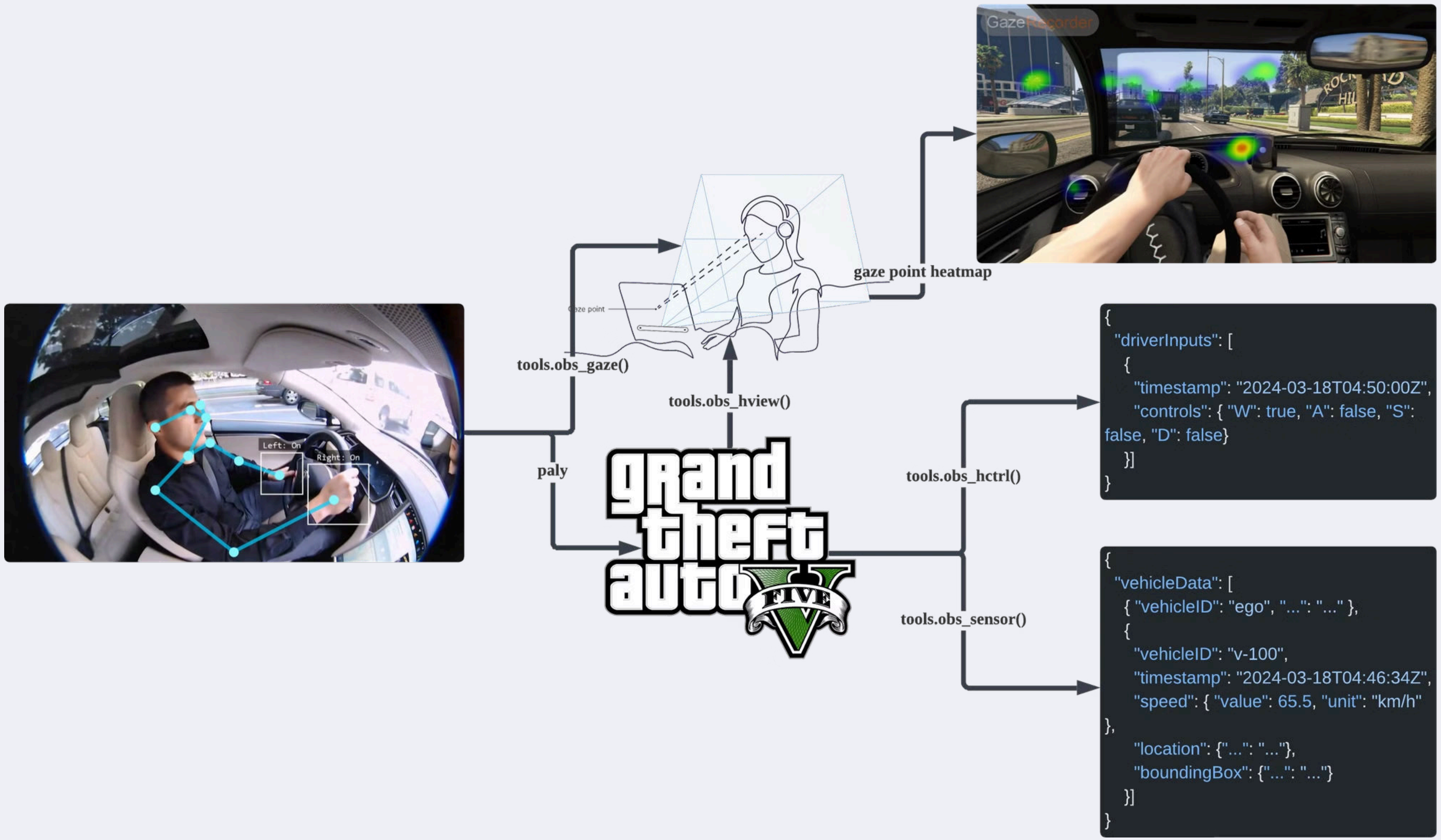


3.2.1 Tools API



References: Script Hook V[1], SHVDN[2], GTAV[3] and Whisper[4].

3.2.2 Data Collection



Tools used: iVCam[1], Beam Eye Tracker[2] and OpenTrack[3].

3.2.3 Prompt Engineering

1. Tactics (under the guide[1] from OpenAI)

1 Include detailed information in the query to obtain more relevant answers.

2 Ask the model to adopt a persona.

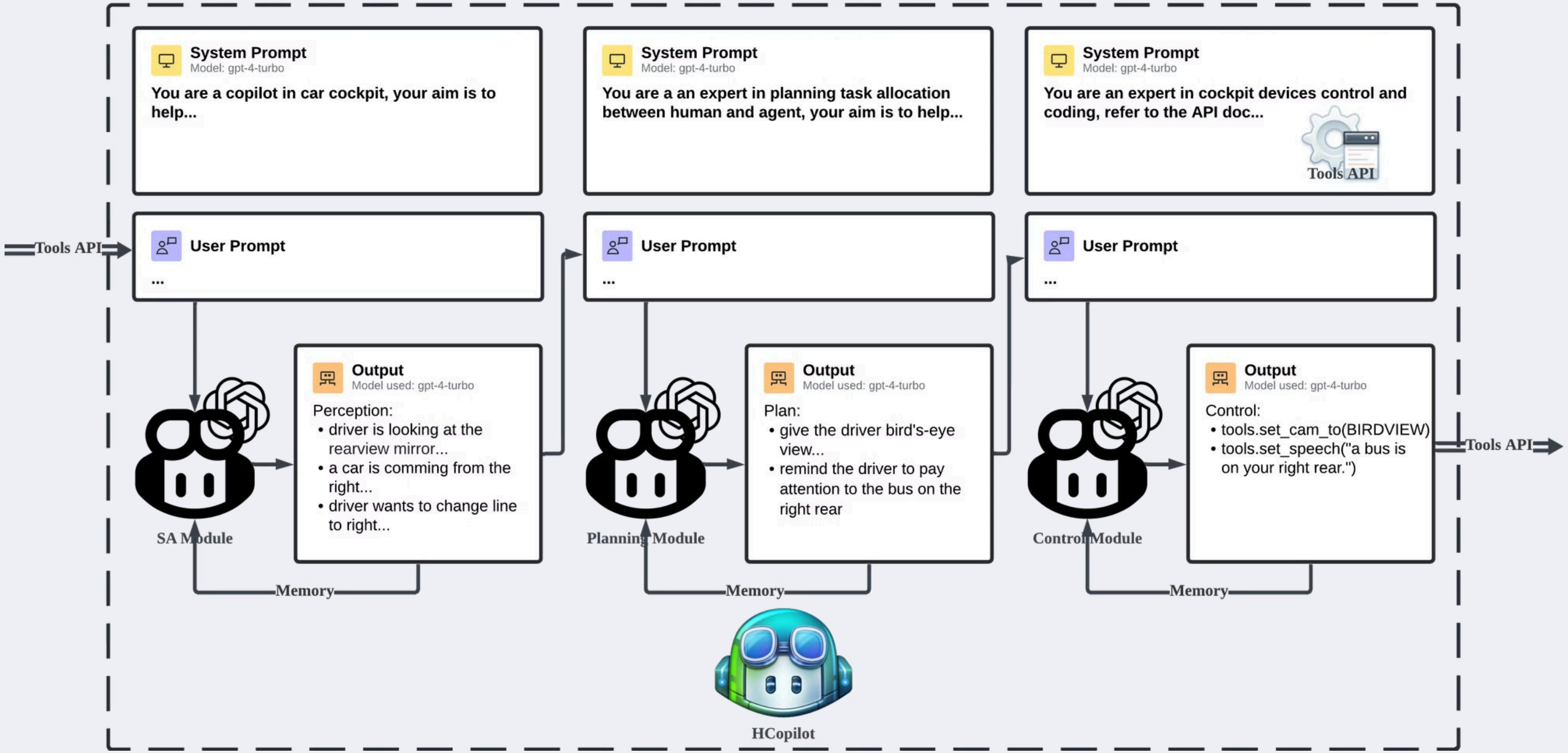
3 Use delimiters to clearly indicate different parts of the input.

4 Follow the chain-of-thought (CoT) prompting[2], specifying the steps required to complete the task.

5 Provide examples.

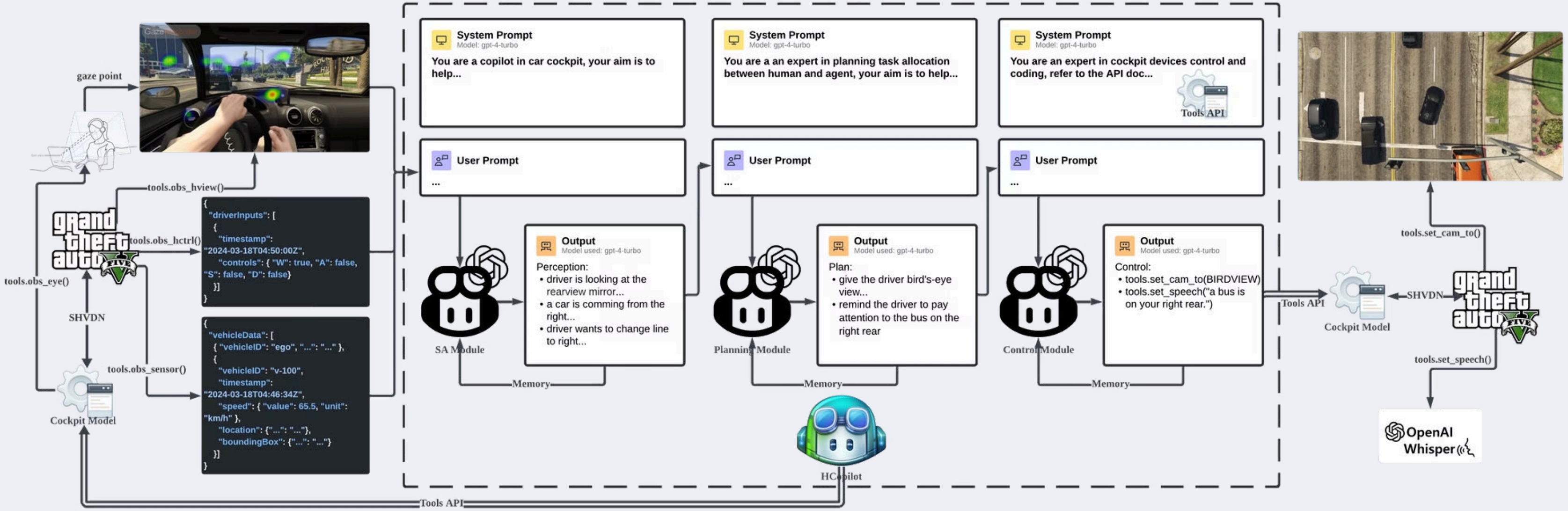
Prompt, also known as the input to LMM, is the description of the input data and the tasks.

2. LMMs Chain



Implemented using LangChain[1], an open-source framework to dev apps powered by LMMs.

3.2.4 Overall Workflow

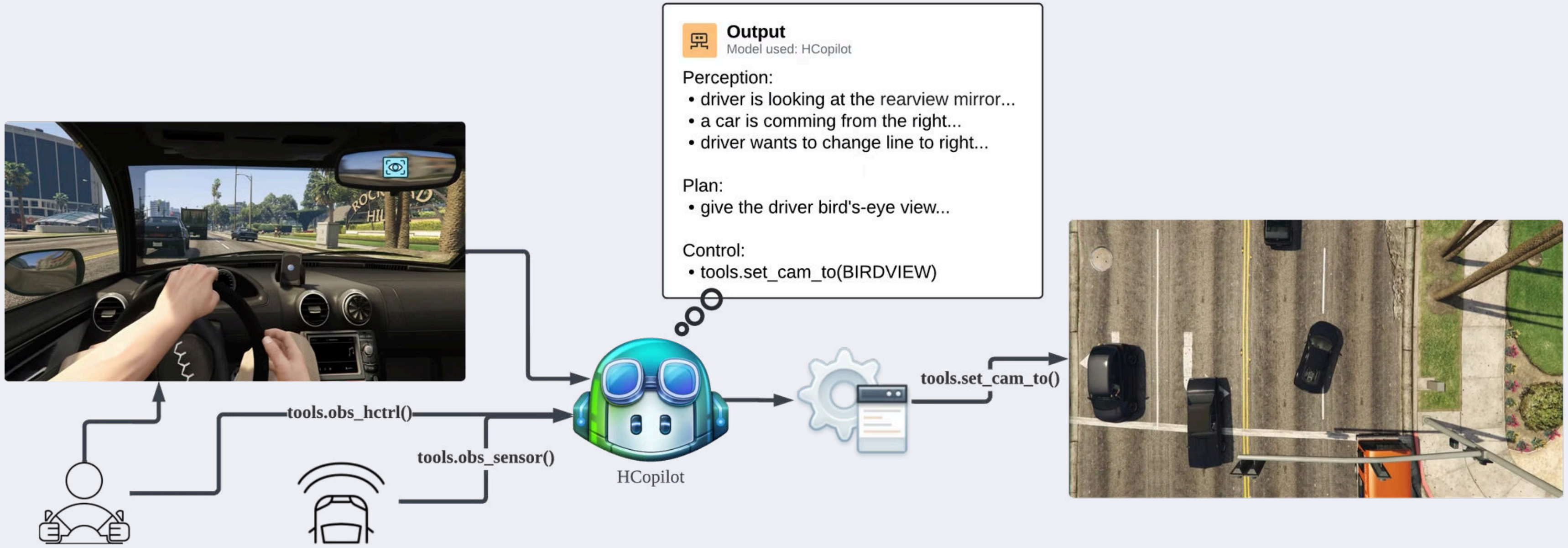


4. Demonstration

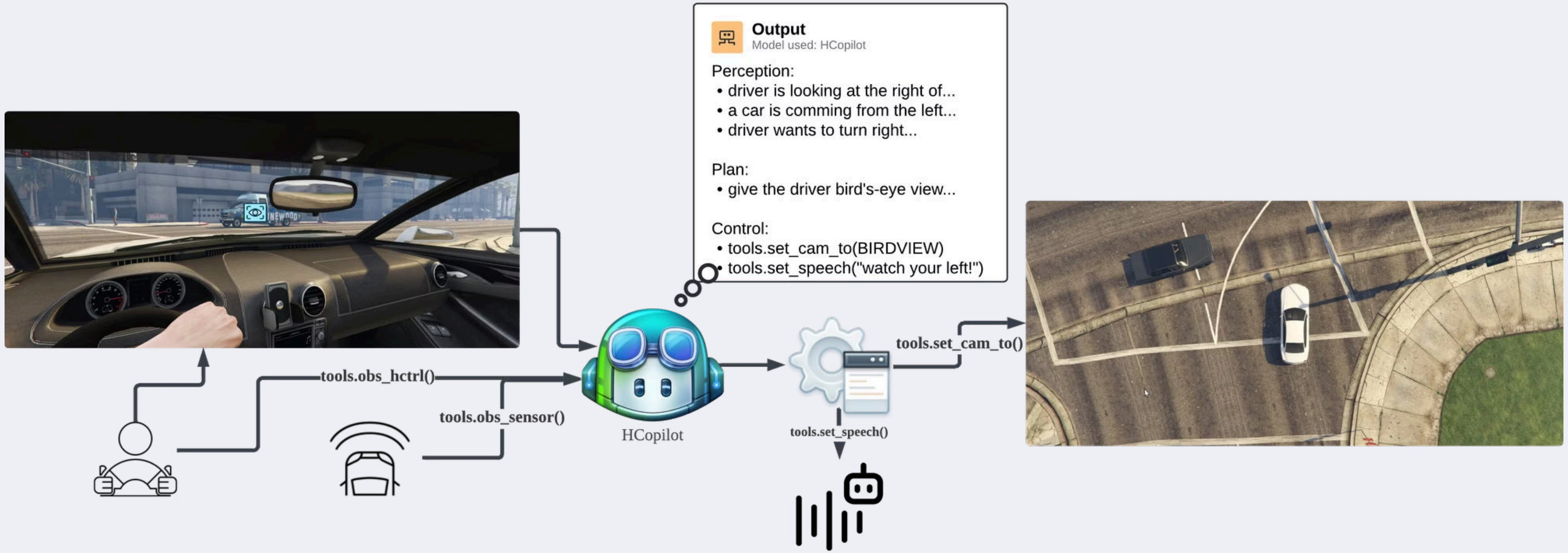
Open in JupyterLab

Open in GitHub

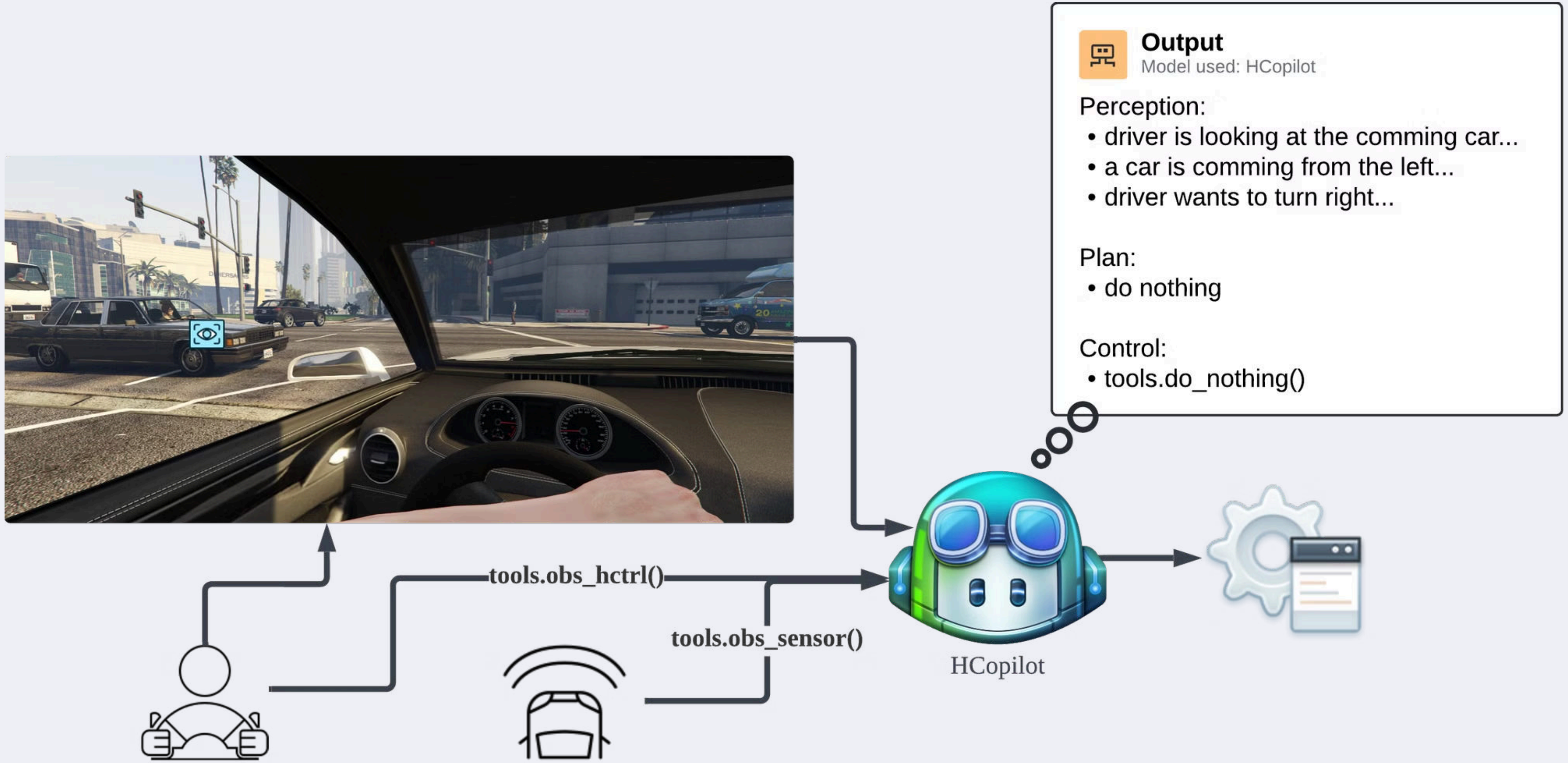
Scenario 1: Lane Change



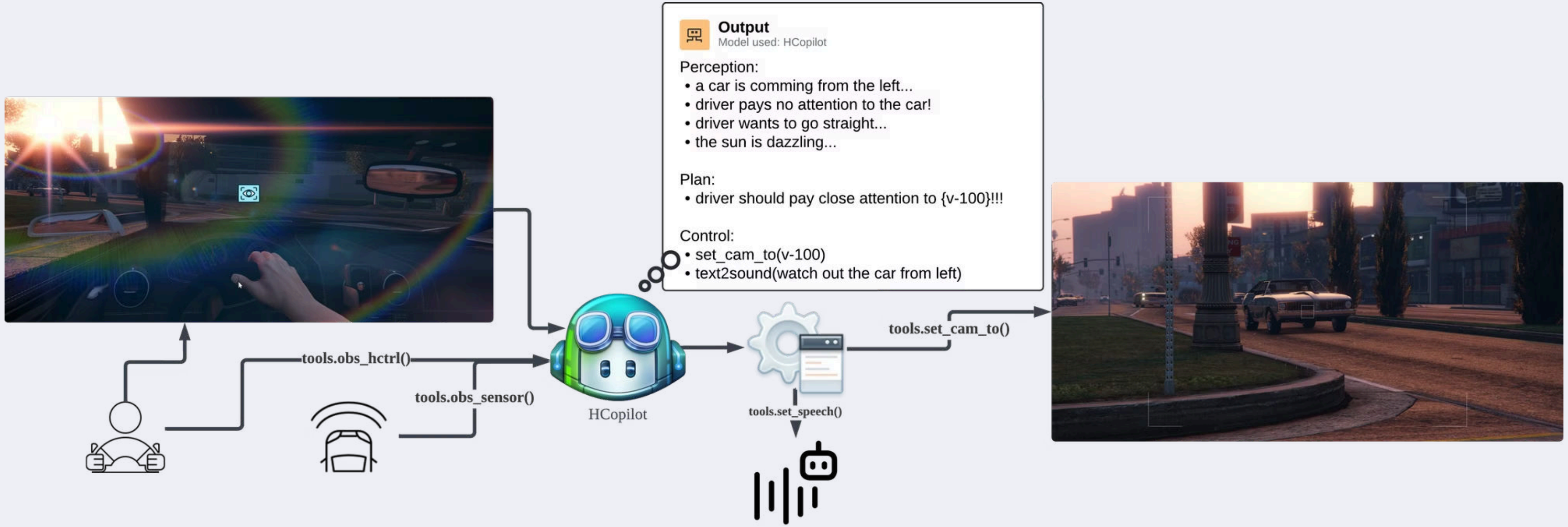
Scenario 2: Turn Right at Intersection 1



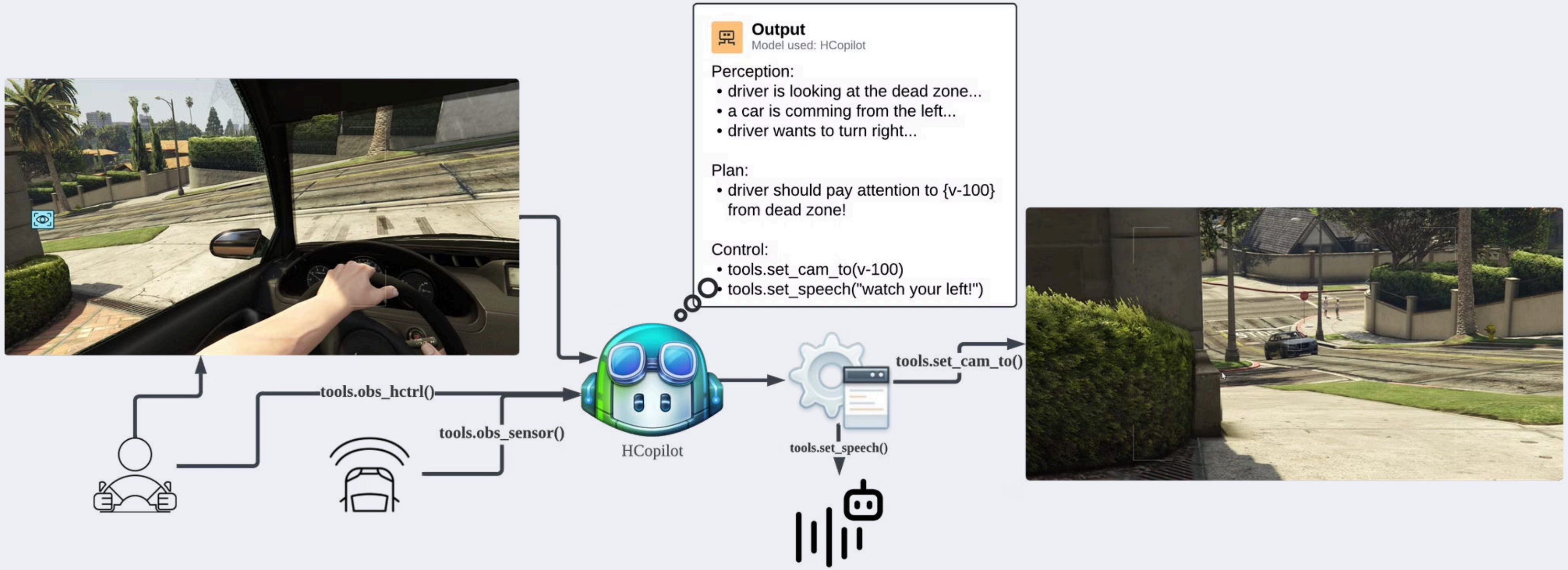
Scenario 2: Turn Right at Intersection 2



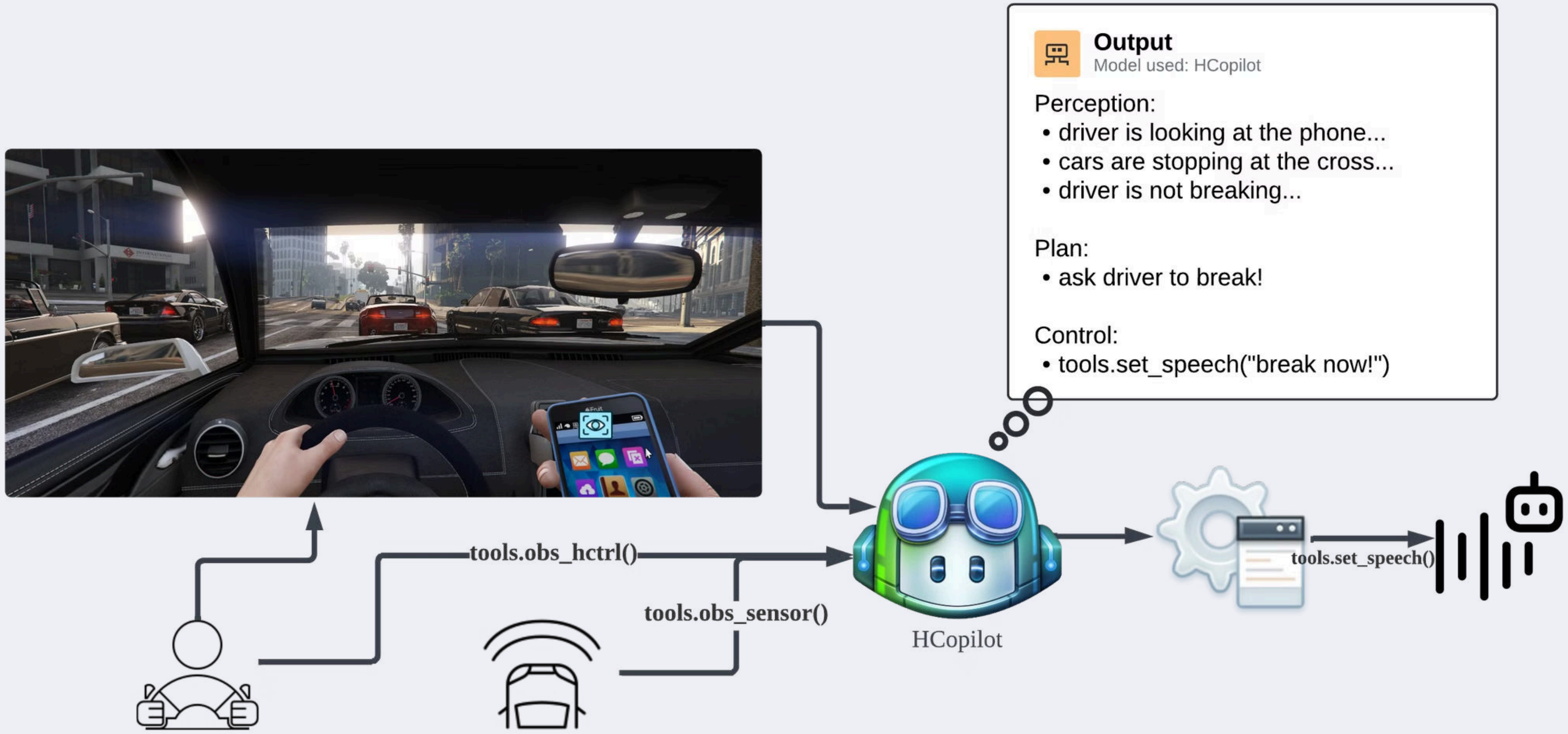
Scenario 3: Too Bright to See



Scenario 4: Blind Area



Scenario 5: Low Attention



5. Experiments

5.1 Experiment Design Overview

1. Participants

- **10 experienced drivers**
- **Engage in multiple predefined driving scenarios**

2. Driving Scenarios

- **5 different scenarios**: lane change, turn right, blind area, low attention, strong light
- **Conducted in a simulator**: ensures controllability and safety

3. Data Collection

- **Simulator data**: operations, eye-tracking, external environment
- **HCopilot data**: perception, planning, control
- **Driver subjective feedback**: questionnaires

4. Metrics

- **7 expert evaluation metrics**: cover perception, planning, control
- **Cross-modal entity alignment**:
  - Aligning driver's first-person view with vehicle external sensor data
- **Tool usage success rate**:
  - Recording success and failure of control commands

5.2 Evaluation Data

Driver ID	Scenario ID	Intent Detection (1-10)	Attention Detection (1-10)	Environment Understanding (1-10)	Threat Prediction (1-10)	SA Improve-ment (1-10)	Safety Improve-ment (1-10)	Adaptive Assistance (1-10)	Cross-modal Entity Alignment (%)	Tool Usage Success Rate (%)
D1	S1	9	8	9	8	8	9	8	85	95
D1	S2	8	7	8	7	7	8	7	80	92
D1	S3	9	9	9	8	9	9	8	88	96
D2	S1	9	8	9	8	8	9	8	83	94
D2	S2	8	7	8	7	7	8	7	78	91
D2	S3	9	8	9	8	8	9	8	82	93
D3	S1	7	6	7	6	6	7	6	75	90
D3	S2	8	7	8	7	7	8	7	77	89
D3	S3	8	7	8	7	7	8	7	79	91
D4	S1	9	8	9	8	8	9	8	86	95

5.3 Descriptive Statistics Table

Metric Name	Mean	Std Dev	Min	Max
Intent Detection	8.20	0.83	7	9
Attention Detection	7.33	0.81	6	9
Environment Understanding	8.20	0.83	7	9
Threat Prediction	7.33	0.81	6	9
SA Improvement	7.33	0.81	6	9
Safety Improvement	8.20	0.83	7	9
Adaptive Assistance	7.33	0.81	6	9
Cross-modal Entity Alignment (%)	80.10	4.15	74	88
Tool Usage Success Rate (%)	92.54	2.30	89	96

6. Conclusion and Future Work

Conclusion

1. Proposed a novel HAC model (HCockpit) considering both human intention and explanable communication
2. Implemented an copilot agent (HCopilot) powered by the SOTA LMM GPT-4 Turbo, with the following abilities:
   a. Effective Enhancement of Situation Awareness
   b. Timely Threat Perception and Warning
   c. Adaptive and Intelligent Assistance

Future Work

1. Local Real-Time Operation of LMMs
2. Entity Alignment Optimization
3. Unified and Standardized Cockpit Device Control Interface
4. Conduct further validation across a broader demographic

Thank You!