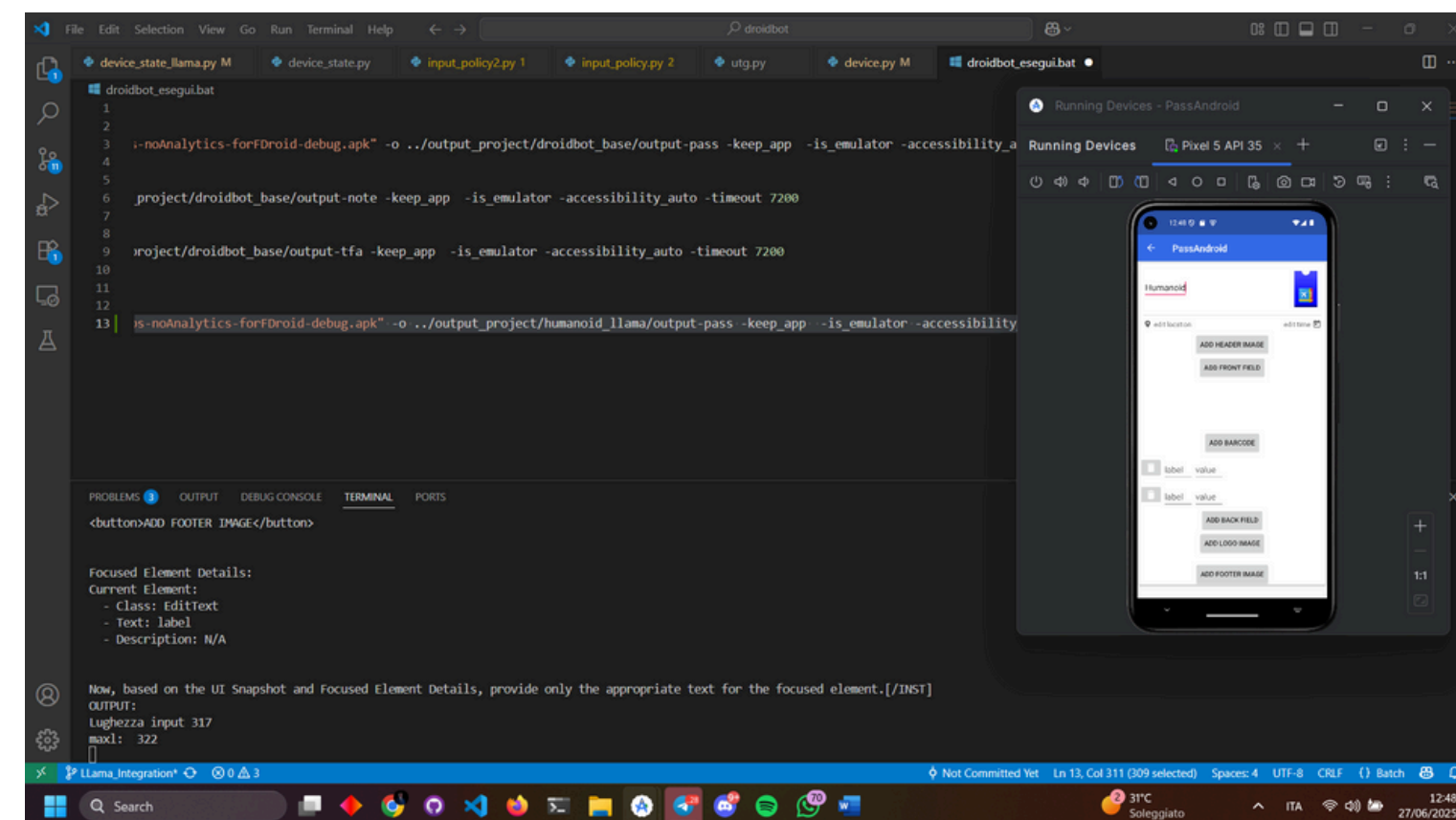




POLITECNICO DI TORINO

Large Language Models 2024/2025

# Context-Aware GUI Testing con LLMs



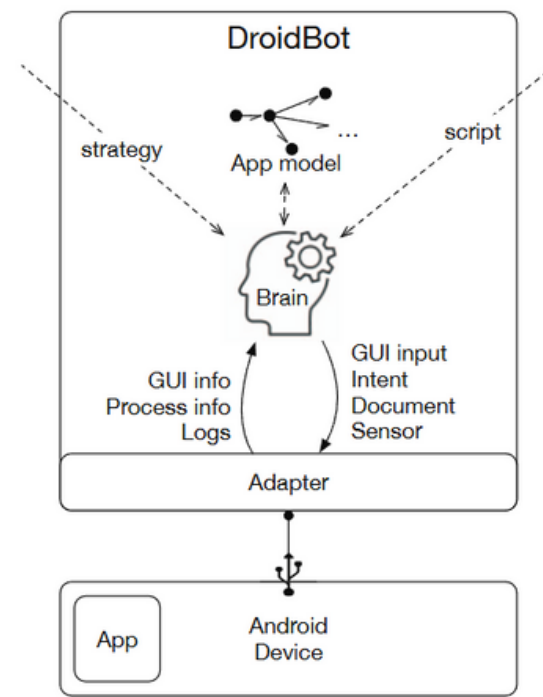
Presentation by : A3

Michele Russo, Raffaele Martone, Giuseppe Monteasi  
s326522, s324807, s319203

# Main GUI Test Framework

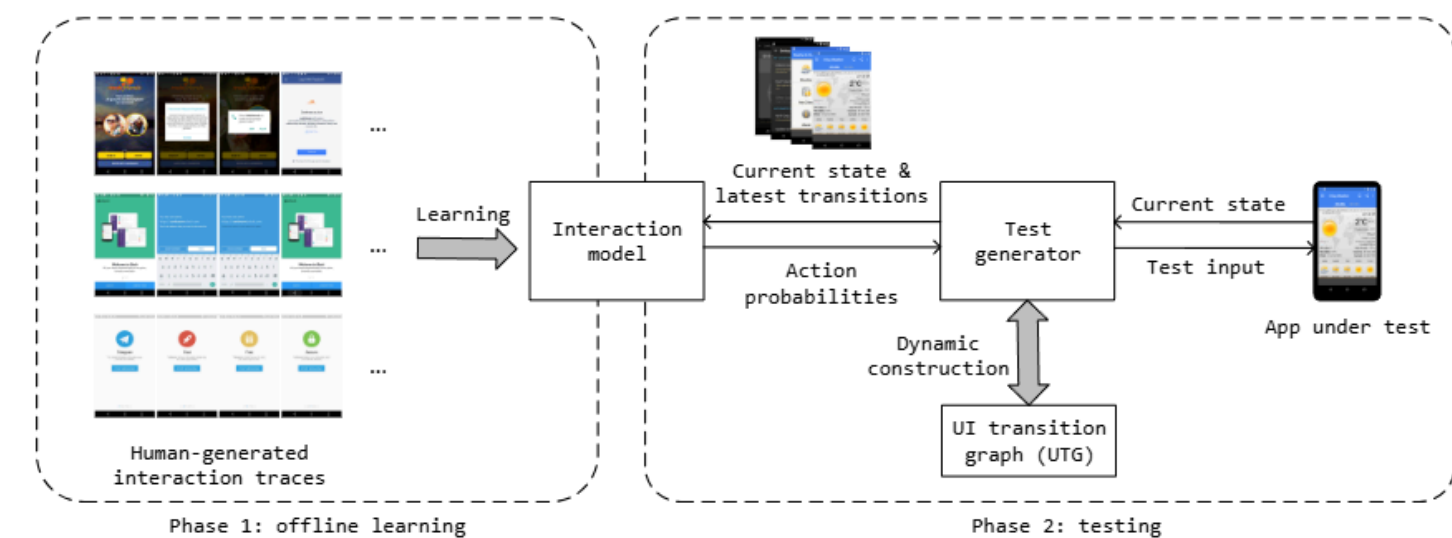
## DROIDBOT

DroidBot is a lightweight, open-source tool for automated test input generation on Android apps. Unlike random event generators, it analyzes the UI hierarchy and device state in real time, building a dynamic graph of UI states and transitions. This enables systematic, deep exploration and richer coverage, making DroidBot effective at uncovering behaviors that only appear under specific conditions.



## HUMANOID

Humanoid is an advanced input generator that integrates deep learning to simulate realistic user interactions. Trained on large-scale human interaction data, it predicts which UI elements real users would select and what actions they would take. By combining visual feature extraction and sequence modeling, Humanoid explores the app more like a real user, reaching GUI states often missed by traditional or random approaches.



# The Core Problem

Traditional mobile testing frameworks have a critical limitation

## Main problem

- **DroidBot** and **Humanoid** only insert "Hello World" in text fields or pre-setted input
- Inability to overcome screens requiring specific inputs
- Limited coverage of real app functionalities

Result > 00-Droidbot Base > resultati\_output-note.json > {} 0 > description

```
1 [{"id": "event_2025-06-25_181300.json",
2   "description": "cld=it.feio.android.omninotes.alpha:id/search_src_text",
3   "text": "Hello World",
4   "correct": true
5 },
6 {"id": "event_2025-06-25_181308.json",
7   "description": "class=android.widget.AutoCompleteTextView, resource_id=it.feio.a
8   "text": "Hello World",
9   "correct": true
10 },
11 {"id": "event_2025-06-25_181323.json",
12   "description": "class=android.widget.AutoCompleteTextView, resource_id=it.feio.a
13   "text": "Hello World",
14   "correct": true
15 },
16 {"id": "event_2025-06-25_181703.json",
17   "description": "class=android.widget.EditText, resource_id=it.feio.android.omnin
18   "text": "Hello World",
19   "correct": true
20 },
21 {"id": "event_2025-06-25_182225.json",
22   "description": "class=android.widget.EditText, resource_id=it.feio.android.omnin
23   "text": "Hello World",
24   "correct": true
25 },
26 {"id": "event_2025-06-25_182233.json",
27   "description": "class=android.widget.EditText, resource_id=it.feio.android.omnin
28   "text": "Hello World",
29   "correct": true
30 },
31 {"id": "event_2025-06-25_182829.json",
32   "description": "class=android.widget.EditText, resource_id=it.feio.android.omnin
33   "text": "Hello World",
34   "correct": true
35 },
36 {"id": "event_2025-06-25_183059.json",
37   "description": "class=android.widget.EditText, resource_id=it.feio.android.omnin
38   "text": "Hello World",
39   "correct": true
40 }]
```

id	Text	Valid
event_2025-06-25_181300.json	Hello World	x
event_2025-06-25_181308.json	Hello World	x
event_2025-06-25_181323.json	Hello World	x
event_2025-06-25_181703.json	Hello World	x
event_2025-06-25_182225.json	Hello World	x
event_2025-06-25_182233.json	Hello World	x
event_2025-06-25_182252.json	Hello World	x
event_2025-06-25_182336.json	Hello World	x
event_2025-06-25_182344.json	Hello World	x
event_2025-06-25_182359.json	Hello World	x
event_2025-06-25_182503.json	Hello World	x
event_2025-06-25_182542.json	Hello World	x
event_2025-06-25_182704.json	Hello World	x
event_2025-06-25_182829.json	Hello World	x
event_2025-06-25_182856.json	Hello World	x
event_2025-06-25_183059.json	Hello World	x

State Details

package it.feio.android.omninotes.alpha

activity it.feio.android.omninotes.MainActivity

state\_str 0bc2e9c92f98570689d2f29265de1f99

structure\_str f835bff3c709da412469d04183af13e3

Created: 17 minutes ago Updated: 17 minutes ago



# Research Questions

## Focus

Measuring effectiveness (working tests) vs coverage (explored states)



- **RQ1:** How effectively can LLMs generate working context-aware test cases for mobile GUI testing?
- **RQ2:** What coverage can be obtained by generating test cases with LLMs?



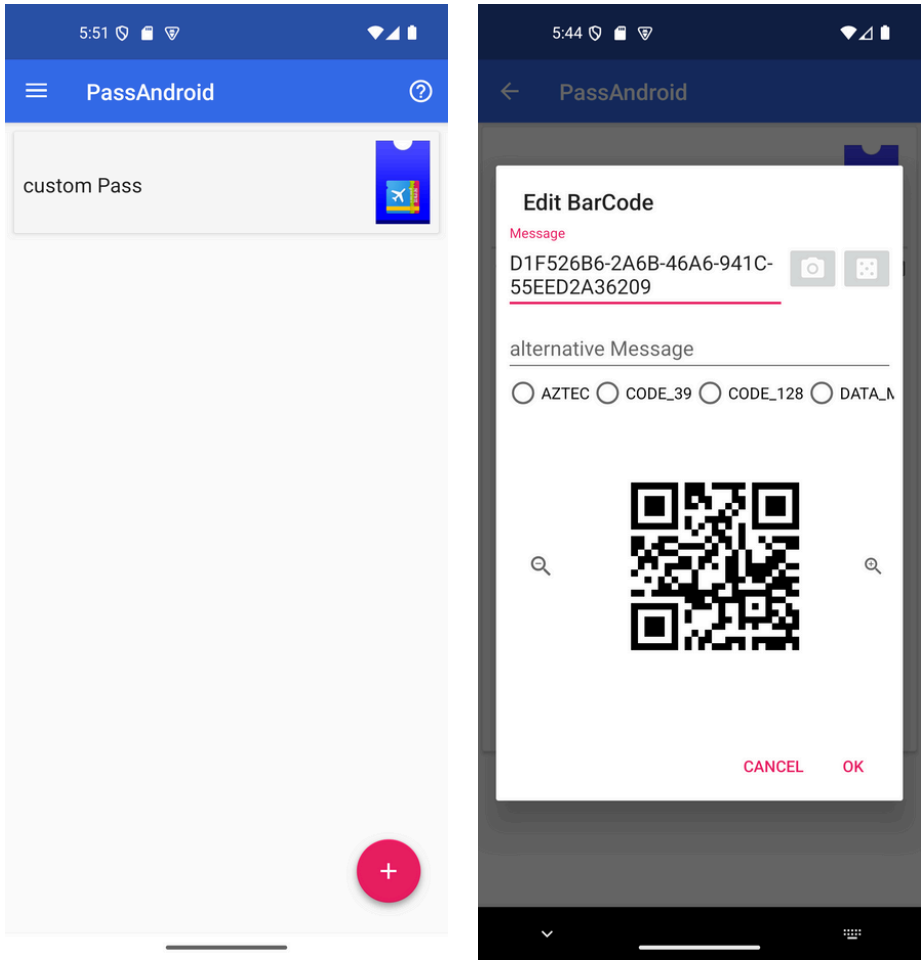
# 3 Tested Apps

05



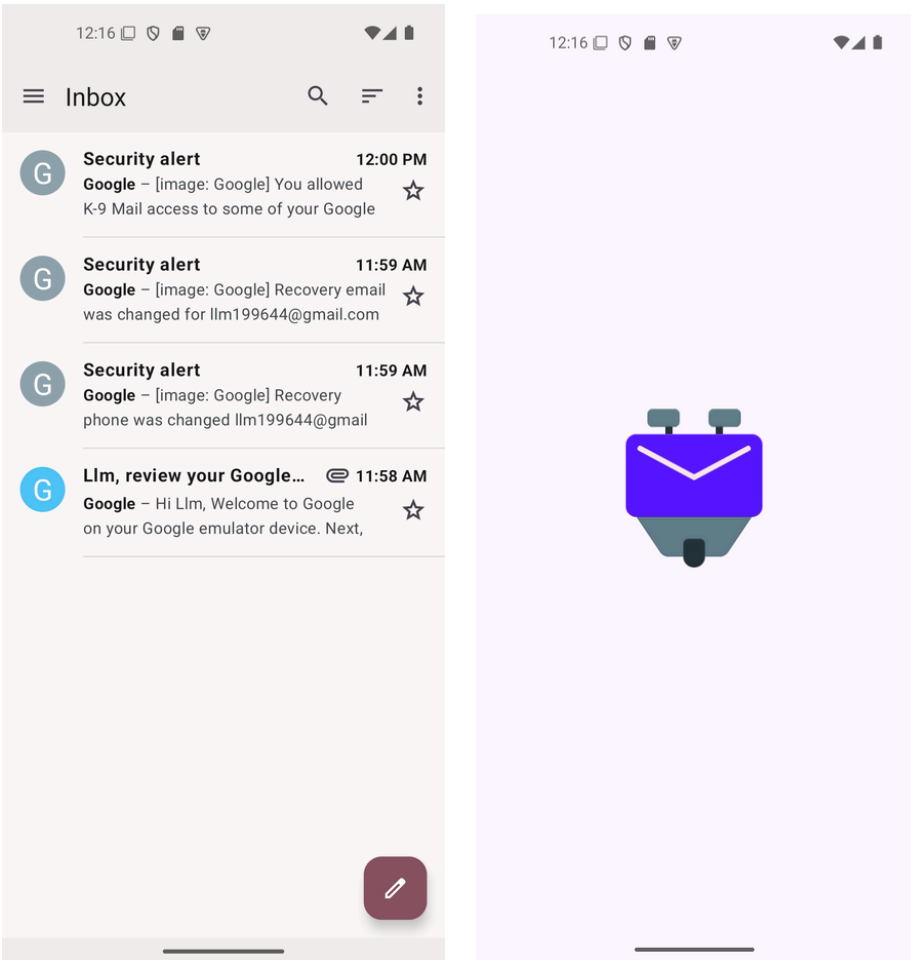
PASSANDROID

Digital pass management



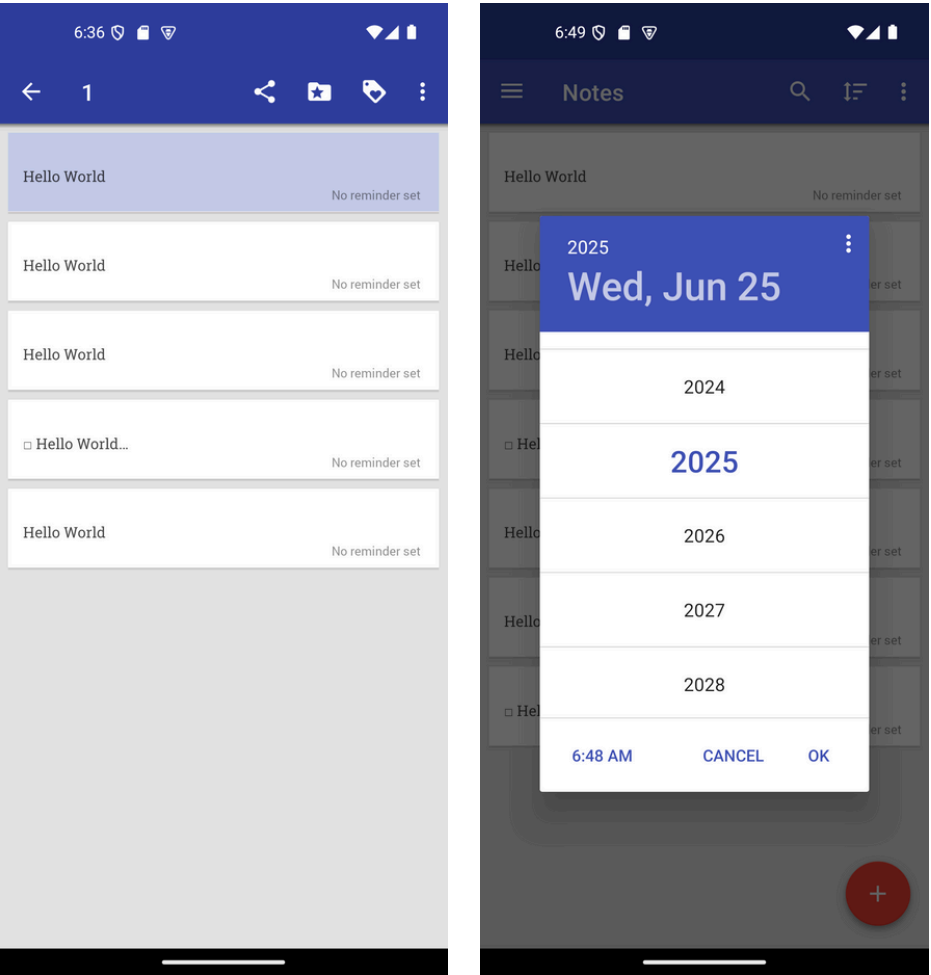
THUNDERBIRD

Email



OMNI-NOTES

Note-taking

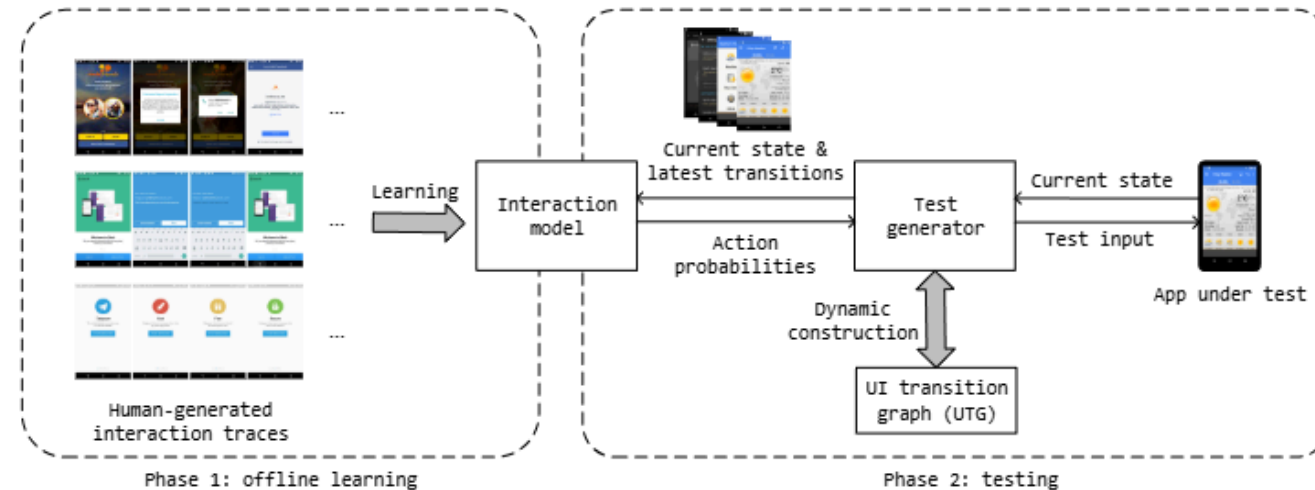




# Methodology - The 7 Configurations

## Baseline

- Droidbot Base
- Humanoid Base

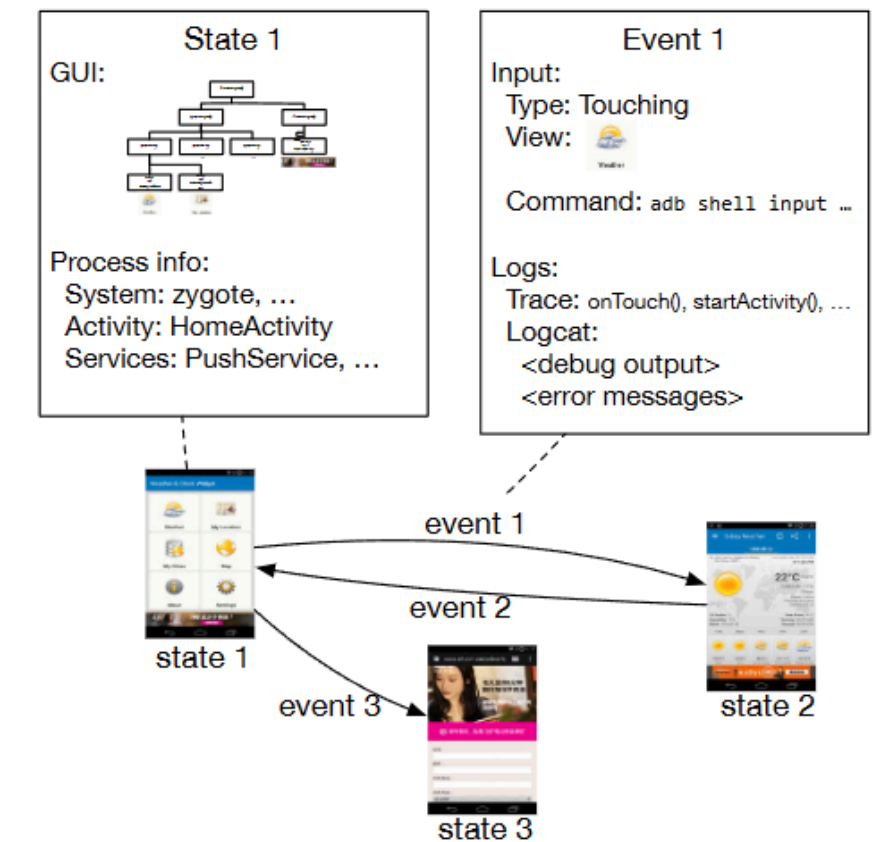
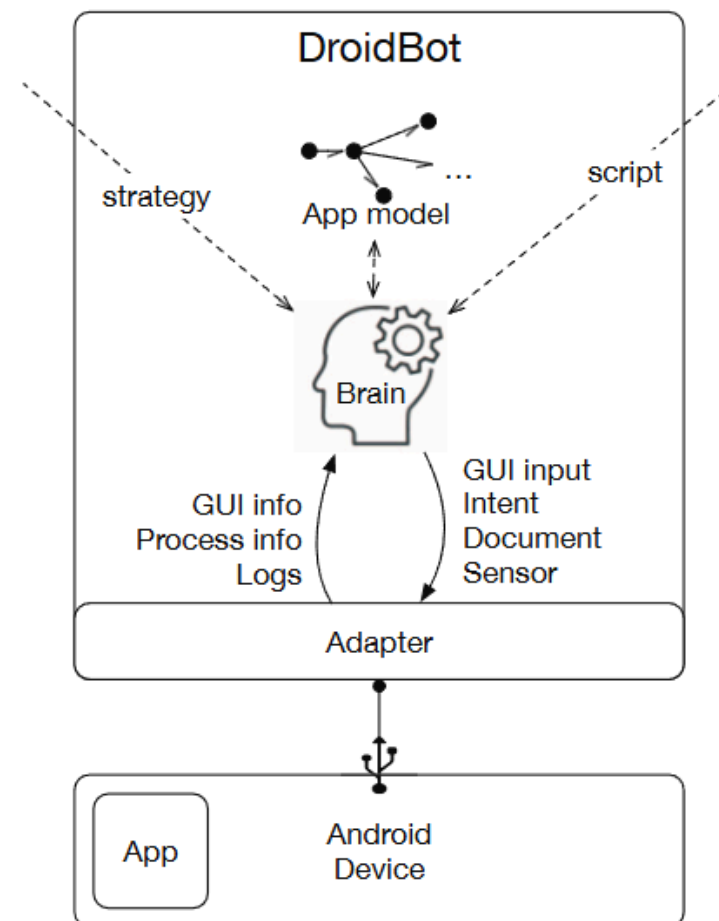


## LLM-Enhanced (Llama-3.2-1B-Instruct)

- Droidbot + LLAMA for textual input
- Droidbot + LLAMA for textual input + Choice
- Humanoid + LLAMA for textual input

## Replay-Enhanced

- Droidbot + Replay output (offline approach)
- Humanoid + Replay output (offline approach)



# LLM Integration - Two Approaches

## Online Approach (Real-time):

- Direct integration into DroidBot/Humanoid code
- Dynamic generation during exploration
- Prompt engineering with few-shot learning

## Offline Approach (Replay):

- Post-processing DroidBot JSON files
- Replacing "Hello World" with contextual texts
- Re-running modified tests

```
Prompt sent to Llama:
<s>[INST] <<SYS>>You are an assistant that generates only a realistic, context-appropriate text input for a UI element. Respond with a single action to take, no explanations, no formatting, no extra symbols.</SYS>>

### Few-Shot Examples:

Example 1:
[UI Representation]
<input id=0 text='Email address' bound_box=10,50,310,100>Enter email</input>
Possible Actions:
0: event_type=touch, desc='Show Calendar List and Settings drawer', resource_id=None, class=android.widget.ImageButton, bounds=[[11, 147], [165, 301]]1: event_type=touch, desc='July', resource_id=com.google.android.calendar:id/date_picker_button, class=android.widget.LinearLayout, bounds=[[166, 147], [650, 301]]2: event_type=touch, desc='Search', resource_id=com.google.android.calendar:id/action_search, class=android.widget.Button, bounds=[[661, 158], [793, 290]]3: event_type=touch, desc='Jump to Today', resource_id=com.google.android.calendar:id/action_today, class=android.widget.Button, bounds=[[793, 158], [925, 290]]Output:
[UI Snapshot]
<button>July</button>

Focused Element Details:
Current Element:
- Class: FrameLayout
- Text: N/A
- Description: N/A

Possible Actions:
0: event_type=touch, desc='Show Calendar List and Settings drawer', resource_id=None, class=android.widget.ImageButton, bounds=[[11, 147], [165, 301]]
1: event_type=touch, desc='July', resource_id=com.google.android.calendar:id/date_picker_button, class=android.widget.LinearLayout, bounds=[[166, 147], [650, 301]]
2: event_type=touch, desc='Search', resource_id=com.google.android.calendar:id/action_search, class=android.widget.Button, bounds=[[661, 158], [793, 290]]
3: event_type=touch, desc='Jump to Today', resource_id=com.google.android.calendar:id/action_today, class=android.widget.Button, bounds=[[793, 158], [925, 290]]
4: event_type=touch, desc='Signed in as llm llm199644@gmail.com'
```

07



# Prompt Engineering

## Text Input Prompt

This prompt instructs the LLM to generate a realistic, context-aware text input for a UI element, based on the interface structure and properties. It uses few-shot examples and requires the output to be concise, context-matching, and without any extra formatting or symbols.

```
def ask_llama(self, view, max_l=200, temp=0.7, full_view_representation=None):
    representation = ""
    for line in full_view_representation.split('\n'):
        type = line.split('<')[1].split(' ')[0]
        line = line.split('>')[1].split('<')[0]
        if len(line) > 0:
            representation += f"<{type}>" + line + "</" + type + ">\n"
    full_view_representation = representation
    # Generate a brief description of the current element based on available attributes
    view_text = self._safe_dict_get(view, 'text', default='').strip()
    content_description = self._safe_dict_get(view, 'content_description', default='').strip()
    view_class = self._safe_dict_get(view, 'class', default='').split('.')[0]

    # Build a readable summary for the current view
    view_details = (
        f"Current Element:\n"
        f" - Class: {view_class}\n"
        f" - Text: {view_text if view_text else 'N/A'}\n"
        f" - Description: {content_description if content_description else 'N/A'}\n"
    )

    # Construct a structured prompt that incorporates both the global UI representation
    # and the details of the active view
    prompt = (
        f"<s>[INST] <<SYS>>"
        "You are an assistant that generates only a realistic, context-appropriate text input for a UI element. "
        "Respond with a single word of plain text, no explanations, no formatting, no extra symbols."
        "<</SYS>>\n\n"
        "### Few-Shot Examples:\n\n"
        "Example 1:\n"
        "[UI Representation]\n"
        "<input id=0 text='Email address' bound_box=10,50,310,100>Enter email</input>\n"
        "Output:\n"
        "john.doe@example.com\n\n"
    )
```

08

```
<s>[INST] <<SYS>>
You are a helpful assistant designed to generate context-aware
text inputs for UI elements.
Analyze the interface structure, element properties, and
existing content to suggest realistic values.
<</SYS>>
### Task Description:
1. Given the current UI state and a focus element (marked as
   editable):
2. Suggest a text input that matches the element's context.
3. The output MUST be few words, without any additional
   explanations or formatting or symbols.
4. The output MUST be a single line of text.
5. The output MUST be different from previous texts.
6. Follow these guidelines:
   - Use actual data formats (emails, names, numbers) when
     detectable
   - Mirror the style of existing content when applicable
   - Prioritize content descriptions over placeholder texts
   - Keep inputs minimal but meaningful

### Few-Shot Examples:
Example 1:
[UI Representation]
<input id=0 text='Email address' bound_box=10,50,310,100>Enter
email</input>
Output:
john.doe@example.com

Example 2:
[UI Representation]
<input id=1 text='Search bar' bound_box=20,100,300,150>Search
products...</input>
<button id=2 text='Search' bound_box=320,100,620,150></button>
Output:
wireless headphones

### Current Interface:
{full_view_representation}
### Focus Element Details:
{view_details}

### Instruction:
Based on the above context, suggest appropriate text for the
focus element.
Provide only the raw text input without explanations, symbols
or formatting, JUST TEXT. [/INST]

OUTPUT:
```



# Prompt Engineering

## Action Selection Prompt:

This prompt asks the LLM to select the most appropriate action for the current UI state from a list of possible actions, using context from the UI snapshot, focused element details, and action history. The output must be only the action index, with no explanations or formatting

```
def ask_choice_llama(self,view, maxl=200, temp=0.7, full_view_representation=None,possible_actions=None):
    rrepresentation = ""
    for line in full_view_representation.split('\n'):
        if '<' in line and '>' in line:
            try:
                type = line.split('<')[1].split(' ')[0]
                content = line.split('>')[1].split('<')[0]
                if len(content) > 0:
                    rrepresentation += f"<{type}>{content}</{type}>\n"
            except Exception as e:
                print(f"WARNING: errore nel parsing della riga: {line} -- {e}")
        else:
            # se vuoi ignorare le righe senza tag, lascia pure vuoto
            continue

    full_view_representation = rrepresentation
    # Generate a brief description of the current element based on available attributes
    view_text = self.__safe_dict_get(view, 'text', default='').strip()
    content_description = self.__safe_dict_get(view, 'content_description', default='').strip()
    view_class = self.__safe_dict_get(view, 'class', default='').split('.')[-1]

    # Build a readable summary for the current view
    view_details = (
        f"Current Element:\n"
        f" - Class: {view_class}\n"
        f" - Text: {view_text if view_text else 'N/A'}\n"
        f" - Description: {content_description if content_description else 'N/A'}\n"
    )
```

09

```
<s>[INST] <<SYS>>
You are an assistant that generates only a realistic, context-
appropriate text input for a UI element. Respond with a
single action to take, no explanations, no formatting, no
extra symbols.
<</SYS>>

### Few-Shot Examples:

Example 1:
[UI Representation]
<input id=0 text='Email address' bound_box=10,50,310,100>Enter
email</input>
Possible Actions:
0: event_type=touch, desc='Show Calendar List and Settings
drawer', resource_id=None, class=android.widget.
ImageButton, bounds=[[11, 147], [165, 301]]
1: event_type=touch, desc='July', resource_id=com.google.
android.calendar:id/date_picker_button, class=android.
widget.LinearLayout, bounds=[[166, 147], [650, 301]]
2: event_type=touch, desc='Search', resource_id=com.google.
android.calendar:id/action_search, class=android.widget.
Button, bounds=[[661, 158], [793, 290]]
3: event_type=touch, desc='Jump to Today', resource_id=com.
google.android.calendar:id/action_today, class=android.
widget.Button, bounds=[[793, 158], [925, 290]]
Output:
1

UI Snapshot:
{full_view_representation}

Focused Element Details:
{view_details}

Possible Actions:
{view_possible_actions}

History of Actions:
{view_history_actions}

Now, based on the UI Snapshot, Focused Element Details,
possible actions and History of Actions, provide only the
appropriate index action.
[/INST]
OUTPUT:
```

# PassAndroid Results

## Key Findings

- Both DroidBot and Humanoid simulate realistic user interactions: creating digital passes, filling in fields (title, barcode, header), printing, sharing, editing, and accessing the help menu.
- Baseline configurations (DB, H, Replay) explore few states and activities, with no valid text inputs.
- Integrating LLAMA for text generation (DBL, HL) increases state/edge exploration but does not significantly improve valid text input.
- Only when LLAMA is used for both text and action selection (DLC, HL) do we see more valid text inputs and slightly higher activity coverage (up to 5/15).
- Main limitations: low percentage of valid text fields, UI Automator struggles with menu navigation and external file uploads, limiting full activity coverage.

## 5.1.2 Coverage and Effectiveness

Metric	DB	DBR	DBL	DLC	H	HR	HL
UTG state	110	110	214	77	170	170	119
UTG edge	200	200	2087	232	360	360	230
Activity coverage	4/15	4/15	4/15	5/15	4/15	4/15	5/15
Valid set text	0/66	0/66	0/31	7/182	0/224	0/224	8/289

Table 1: Coverage and effectiveness metrics for PassAndroid across all configurations.

**Legend:** **DB:** DroidBot base, **DBR:** DroidBot + Replay output, **DBL:** DroidBot + LLAMA (text generation), **DLC:** DroidBot + LLAMA + Choice (decision making), **H:** Humanoid base, **HR:** Humanoid + Replay output, **HL:** Humanoid + LLAMA



# Thunderbird Android Results

## Key Findings – TFA Pre-Login

- No method was able to automatically bypass the login screen; exploration was limited to the app’s initial screens.
- Activity coverage and valid text input were both very low across all configurations.
- Integrating LLAMA for text generation did not yield significant improvements due to limited contextual information pre-login.

## Key Findings – TFA Post-Login

- After manual login, all methods explored significantly more states and transitions, enabling deeper app interaction.
- Contextual text generation via LLAMA greatly increased the number of valid text inputs.
- The LLAMA + Choice approach further improved text input effectiveness, demonstrating the benefit of LLM-based selection in richer contexts.

### 5.2.2 Coverage and Effectiveness

Metric	D	DR	DL	DLC	H	HR	HL
UTG state	356	356	15	17	19	19	8
UTG edge	615	615	25	30	34	34	19
Activity coverage	3/31	3/31	2/28	2/28	2/28	2/28	2/28
Valid set text	0/70	12/70	0/10	0/20	0/9	0/9	2/21

Table 2: Coverage and effectiveness metrics for TFA Per-Login across all configurations.

### 5.3.2 Coverage and Effectiveness

Metric	D	DR	DL	DLC	H	HR	HL
UTG state	226	226	30	54	291	291	37
UTG edge	1112	1112	58	86	642	642	79
Activity coverage	3/31	3/31	2/28	2/28	2/28	2/28	2/28
Valid set text	48/101	39/101	8/19	37/93	102/210	30/210	27/28

Table 3: Coverage and effectiveness metrics for TFA Post-Login across all configurations.

**Legend:** **DB:** DroidBot base, **DR:** DroidBot + Replay output, **DL:** DroidBot + LLAMA (text generation), **DLC:** DroidBot + LLAMA + Choice (decision making), **H:** Humanoid base, **HR:** Humanoid + Replay output, **HL:** Humanoid + LLAMA



# Omni-Notes Results

## Key Findings

- Starting with DroidBot base, it interacted with core app features: creating/editing/deleting notes, managing categories, reminders, permissions, and sharing notes.
- Adding LLaMA enabled richer actions: advanced categorization, search, voice dictation, and interaction with calendar activities.
- Humanoid agents performed more human-like actions: uploading files, checklist management, color changes, viewing note details, and password protection.
- Coverage analysis: DroidBot + LLaMA achieved the most states/transitions, while Humanoid agents covered more activities but explored less deeply.
- Integrating LLaMA for action choice improved functional coverage, but sometimes reduced state-space depth.
- Hybrid approaches (LLaMA + Humanoid) balance depth of exploration with variety and realism of interactions.

Metric	DB	DBR	DBL	DLC	H	HR	HL
UTG state	73	73	296	18	169	169	52
UTG edge	173	173	787	32	419	419	125
Activity coverage	3/15	3/15	2/15	1/15	5/15	5/15	3/15
Valid set text	50/62	24/62	25/31	31/85	91/172	100/172	74/158

Table 4: Coverage and effectiveness metrics for Omni-Notes across all configurations.

**Legenda:** **DB:** DroidBot base, **DBR:** DroidBot + Replay output, **DBL:** DroidBot + LLaMA (text generation), **DLC:** DroidBot + LLaMA + Choice (decision making), **H:** Humanoid base, **HR:** Humanoid + Replay output, **HL:** Humanoid + LLaMA





# Answers

13



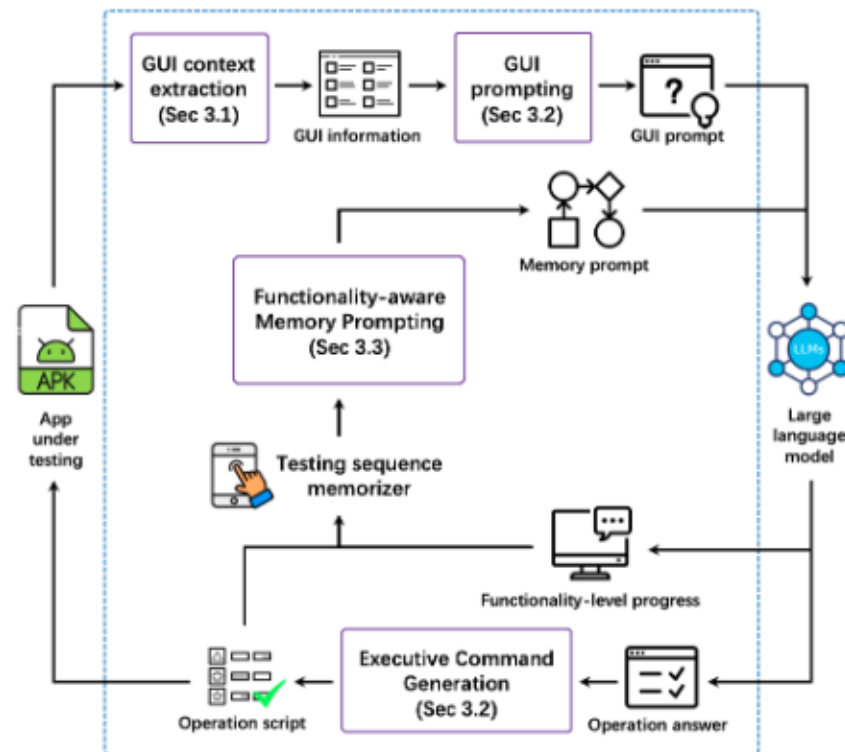
## RQ1 - EFFECTIVENESS ANALYSIS

- LLMs improve context-aware test generation, though quantitative results vary across apps.
- Baseline tools (e.g., DroidBot, Humanoid) rarely produce valid textual inputs.
- LLMs enable more valid inputs.
- Generated tests are more sophisticated and human-like.
- LLMs can handle advanced field completion and complex UI flows.
- Current limitations: hardware constraints, poor UI context descriptiveness, small app sample size.
- Despite practical constraints, LLMs are well-suited for semantic understanding and strategic reasoning in GUI testing.

## RQ2: COVERAGE OF TEST CASES

- LLM-enhanced tools increase path diversity (e.g., 2087 UTG edges with DroidBot + LLAMA).
- More paths do not always lead to broader unique state or activity coverage.
- Many new paths are variations of existing ones.
- Strategic use of LLMs (Choice) boosts activity coverage (e.g., up to 33.3% vs. 26.7% baseline).
- LLMs help reach previously inaccessible app functionalities.
- Strong theoretical potential for diverse input generation and adaptive exploration based on app feedback.

# Identified Limitations and Challenges



## LIMITATIONS

- **Hardware and computational resources** were restricted, limiting exploration and speed.
- **Test execution time was short**, reducing the number of states and transitions discovered.
- **App code and UI metadata were often poorly** descriptive, making it harder for LLMs to generate precise actions.
- **Sample size was small**, as only a few apps were tested, limiting the generalizability of the findings.

## FUTURE IMPROVEMENTS

- **Use more powerful hardware** and allow longer test sessions for deeper exploration.
- **Promote better coding practices** and documentation to provide richer context for LLMs.
- Expand the evaluation to a larger and more **diverse set of apps**.
- **Develop advanced techniques for extracting and structuring context**, enabling LLMs to reason and select actions more effectively.



# Discussion - LLM vs Manual Testing

- LLM-based testing brings clear advantages over manual methods:
  - Higher automation
  - Increased efficiency
  - Ability to generate diverse test cases automatically
- However, it does not fully solve the testing problem.
  - Test quality and coverage are still limited by:
  - Technical constraints (e.g., hardware, tooling)
  - Contextual app limitations
- LLMs greatly reduce manual effort and improve scalability as tech evolves.
  - Yet, further refinement and broader validation are needed.
- **Conclusion:** LLM integration is a promising advance — but not yet a full replacement for manual testing





# Thanks for the attention







# Q&A

