EdgeDroid:

An Experimental Approach to Benchmarking Human-in-the-Loop Applications

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65
126ft
NE
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73°
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5
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SAMSUNG
Drowzee


VIVA TECHNOLOGY
bpifrance
bpifrance


65
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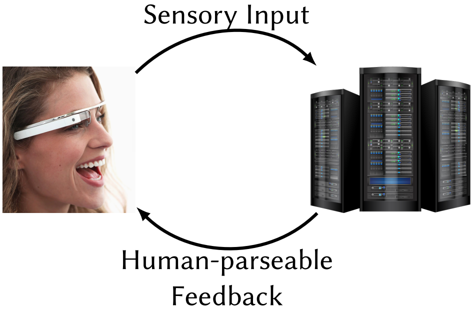
SAMSUNG

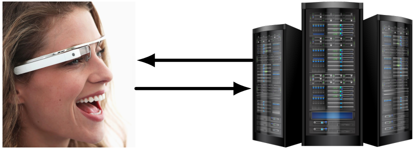

Sensory Input
Human-parseable
Feedback

Studying Human-in-the-Loop Applications

Need to understand and optimize these applications:

- How do they interact with each other?
- How do they interact with infrastructure?
- How do they scale?

With which methodology can we study these behaviors?



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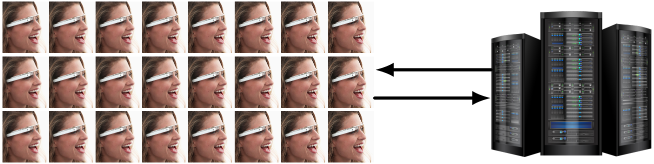

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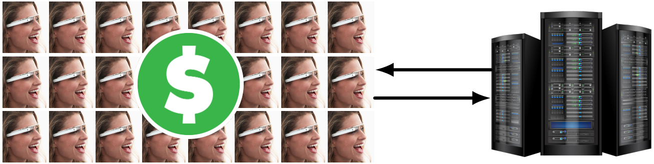

Costly

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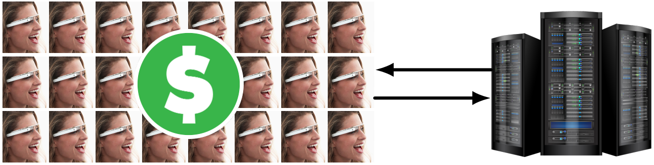


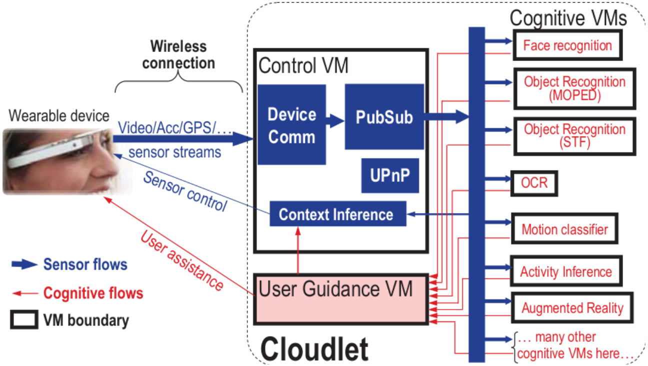
Costly, poor repeatability

Previous & Related Work

Prototyping [1]–[4]

Latencies [5]–[7]

Models [8], [9]



Gabriel Platform (CMU)

Previous & Related Work

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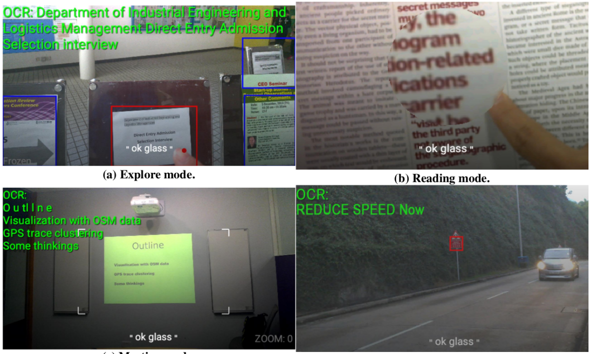


(a) Explore mode. (b) Reading mode.

(c) Meeting mode. (d) Driving mode.

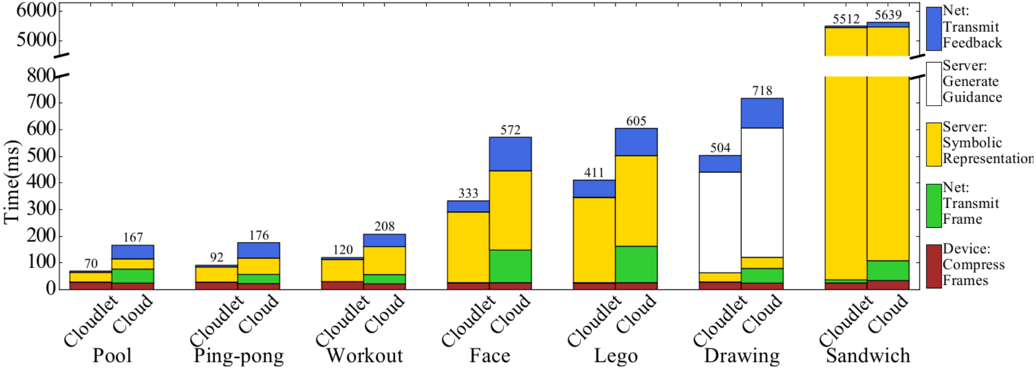
Hyperion Assistant (HKUST)

Previous & Related Work

Prototyping
[1]–[4]

Latencies
[5]–[7]

Models
[8], [9]



Source: Chen *et al.* [5]

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[8], [9]

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Our Contributions

- A methodology for benchmarking human-in-the-loop applications.

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- EdgeDroid: A synthetic workload generator for Human-in-the-Loop applications on Edge infrastructure.

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- A methodology for benchmarking human-in-the-loop applications.
- EdgeDroid: A synthetic workload generator for Human-in-the-Loop applications on Edge infrastructure.
- Experiments and measurements which show the effectiveness of the approach.

Benchmarking… what?

Key question:

In what way is system performance reflected in terms of user experience?

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In what way is system performance reflected in terms of user experience?

Answer: Time

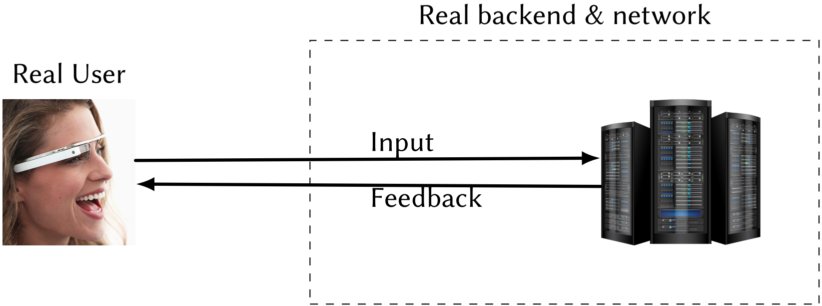
- Latency
- Jitter

Human time-perception is tail-driven…

Users tend to remember worst-case occurrences rather than averages.

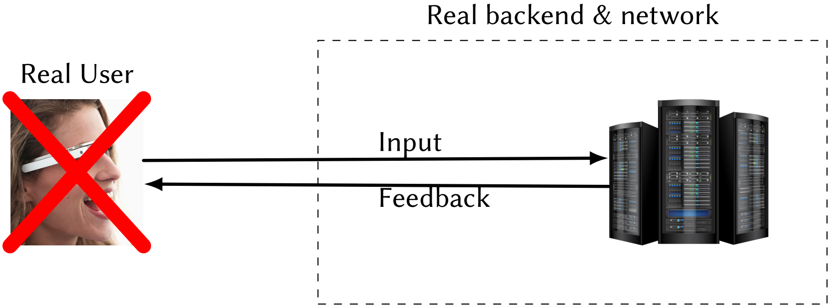
KPIs: Delays (total RTT and segment-wise)

Approach



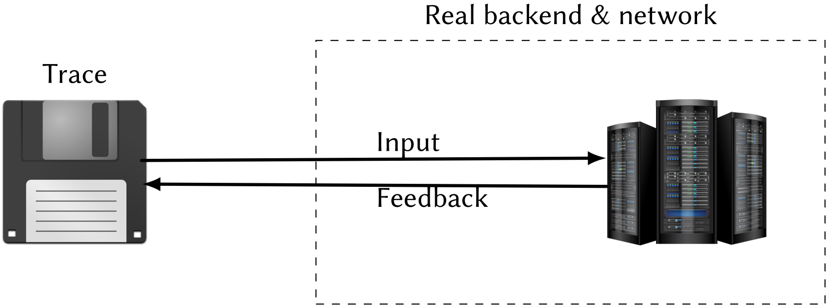
Benchmarking human-in-the-loop applications is HARD

Approach



What if we could do away with the human users?

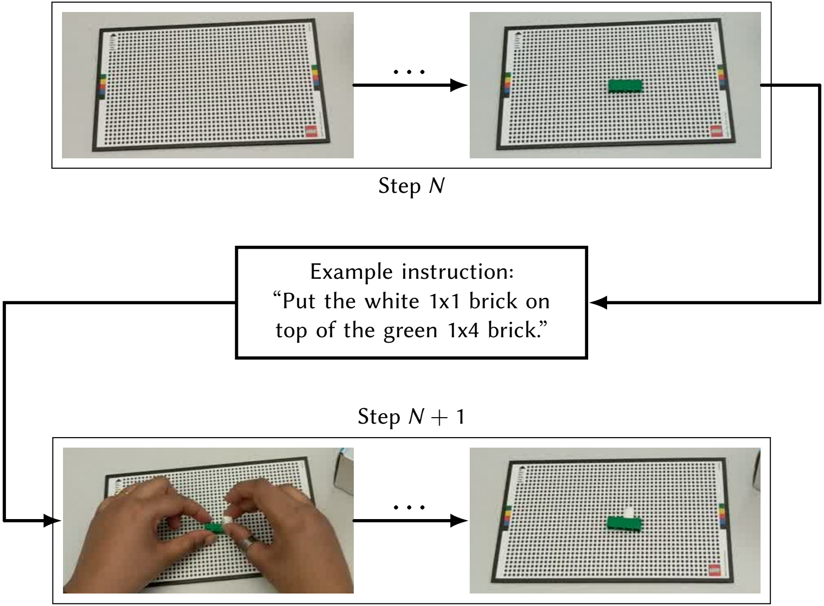
Approach



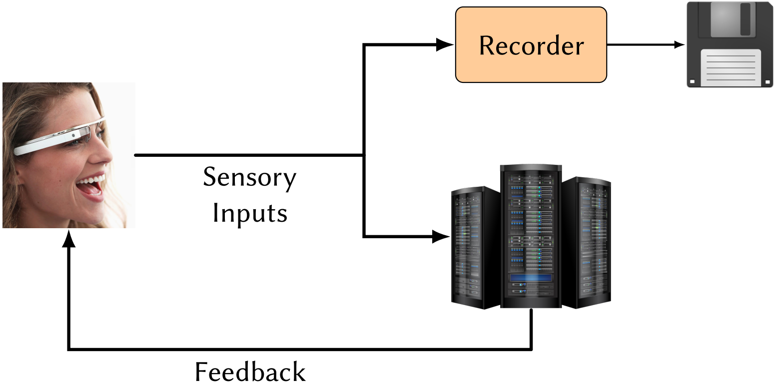
What if we could do away with the human users?

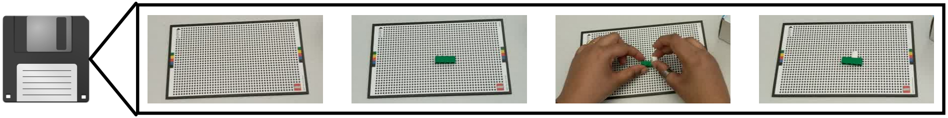
Repeatable, but is it scalable?

Example: Task Guidance Wearable Cognitive Assitance, LEGO [1]



Tracing





Trace Replay

Non-trivial Challenge

- Changes in system responsiveness require adapting trace.
- System delays affect user behavior as well.

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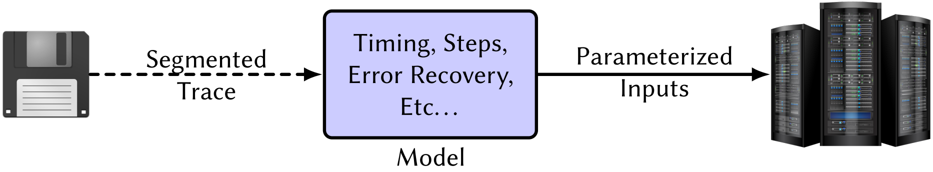
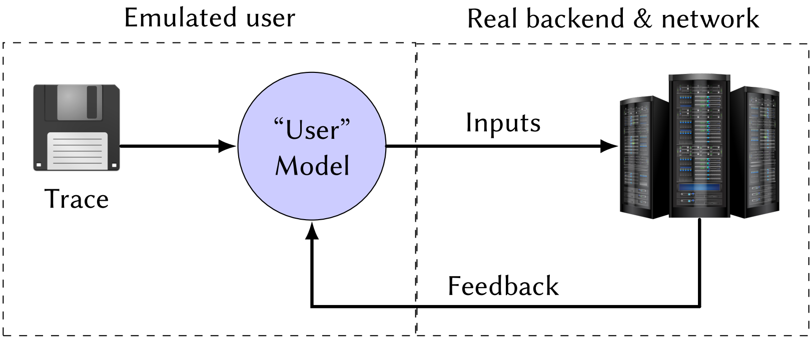
Our Approach

- Segment trace into logical “steps”.
- Controlled replay of steps.

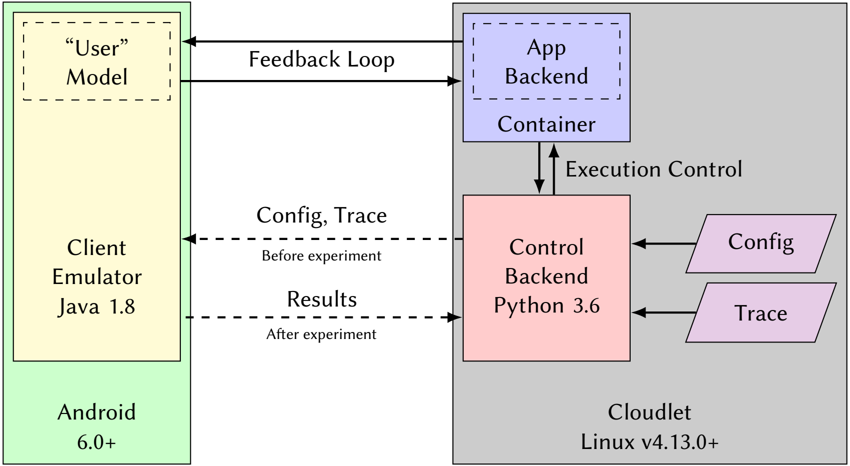


Approach



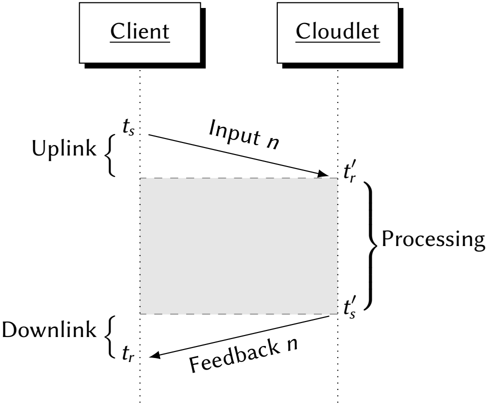
Repeatable, scalable!

Implementation: EdgeDroid



https://github.com/molguin92/EdgeDroid

Timestamping



Clocks are synchronized previous to the experiment.

Timestamps at key points to obtain:

$$\Delta T_{\text{up}} = t'_r - t_s \quad (1)$$

$$\Delta T_{\text{proc}} = t'_s - t'_r \quad (2)$$

$$\Delta T_{\text{down}} = t_r - t'_s \quad (3)$$

$$\Delta T_{\text{total}} = \Delta T_{\text{up}} + \Delta T_{\text{proc}} + \Delta T_{\text{down}} = t_r - t_s \quad (4)$$

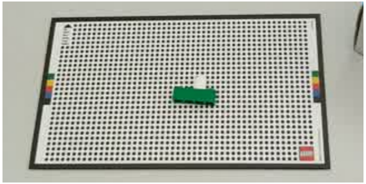
Evaluation

Key purpose:

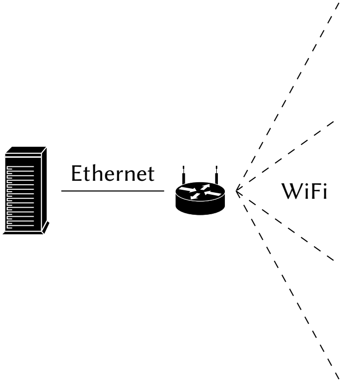
Demonstrate utility of EdgeDroid.

Evaluation: Setup

Application & Scenarios



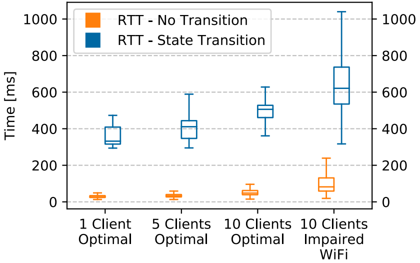
LEGO Assistant



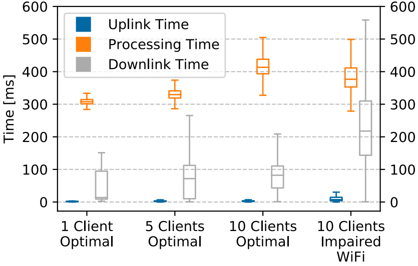
- Three *optimal* scenarios with 1, 5 and 10 devices.
- Weakened wireless link with 10 devices.

Use Cases

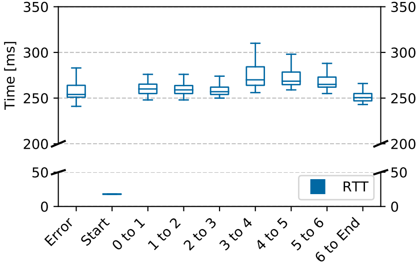
State change vs. no state change.



Times by pipeline segments.



RTT by task step.



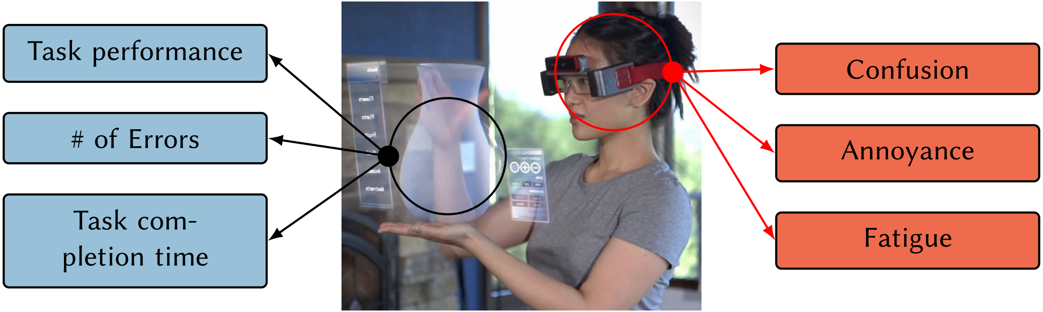
Future Work

- Extending EdgeDroid
  - Characterizing human behavior
  - Extending to other types of applications
- Characterizing Control Performance on Edge Computing Infrastructure

Characterizing human behavior…

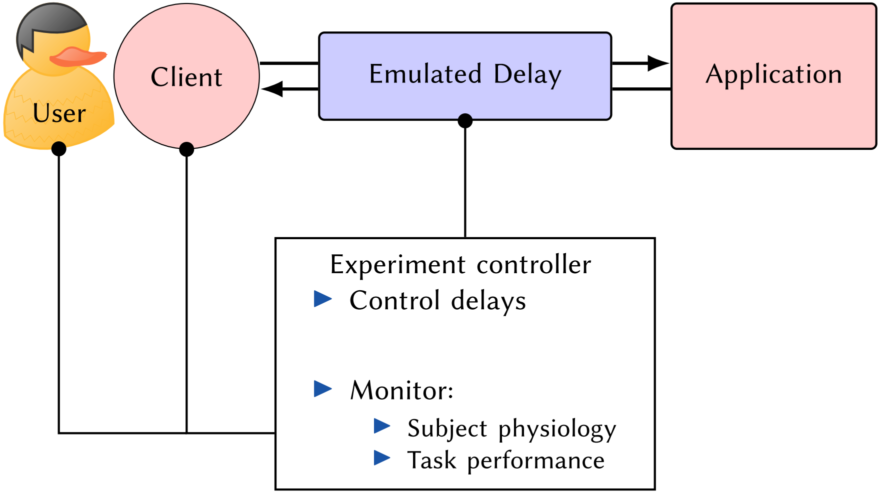
… in the presence of delays in human-in-the-loop applications.

Open research question: how do these delays affect users?



Dabrowski and Munson, "40 Years of Searching for the Best Computer System Response Time" [10]

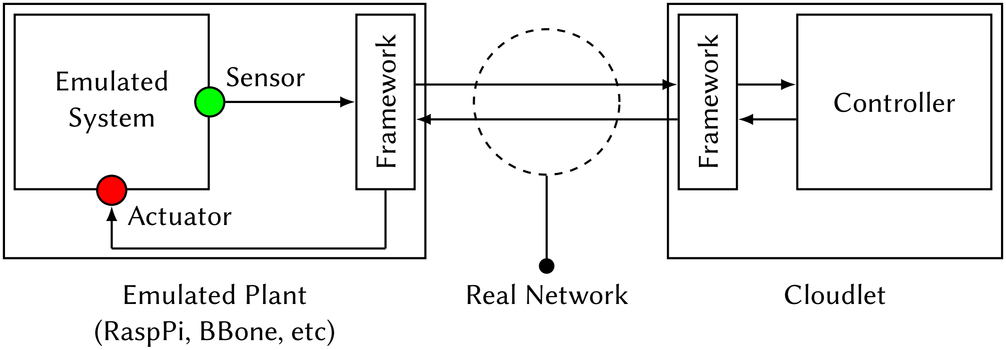
Proposed Experiment Setup



Control Performance on Edge Computing

EdgeDroid for Control Applications

Main focus: study achievable latencies and reliability with off-the-shelf infrastructure. Similar to the NCSBench platform developed at TUM[1][11].



[1] https://github.com/tum-lkn/NCSbench/

Conclusions

Summary

- Need to study the scaling of Human-in-the-Loop applications.
  - Difficult due to human users.
- Methodology + tool suite for benchmarking:
  - **EdgeDroid**
  - Trace based.
  - Model of human behavior.
- Results which show the utility of EdgeDroid.

Future Work

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Acknowledgements

Part of an ongoing collaboration with the Elijah Group at Carnegie Mellon University, led by Prof. Mahadev Satyanarayanan.

Carnegie Mellon University
Computer Science Department

This work was recently presented at HotMobile'19 [12].

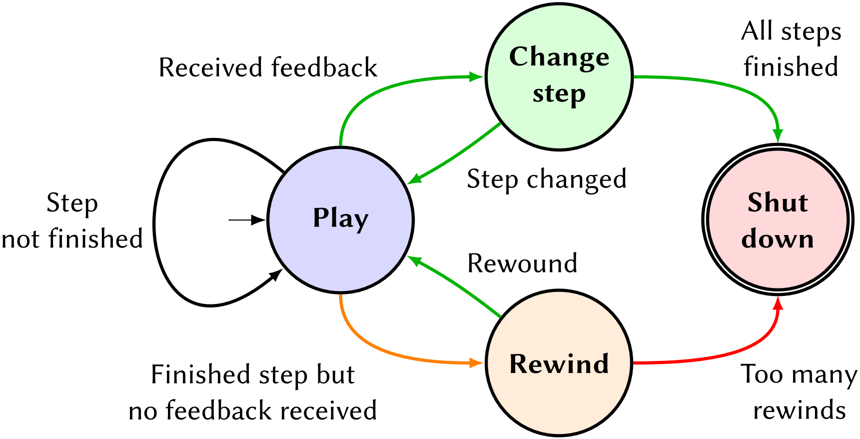
Extra Slides

Requirements

- Generate realistic, high-dimensional, real-time inputs.
- Correctly and realistically react to feedback.
- KPI: Delays.

Trace of pre-recorded inputs & a model of user behavior

User Model



Future work: more elaborate models.

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