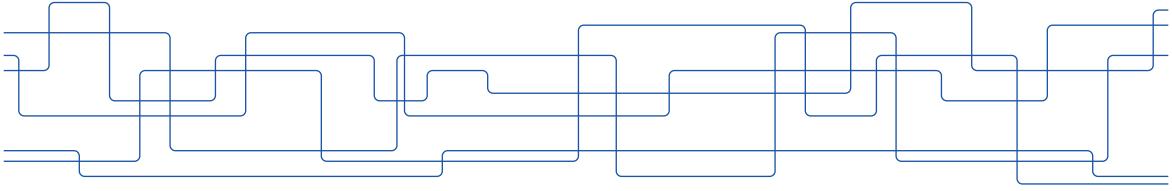
An Experimental Approach to Benchmarking Human-in-the-Loop Applications

Manuel Olguín Muñoz

ISE Internal Seminar, Thursday March 28 2019




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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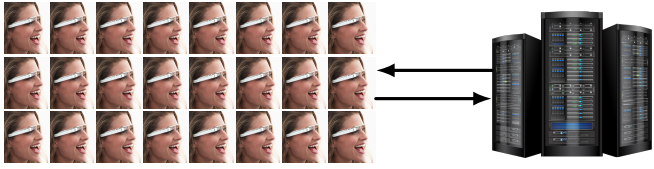

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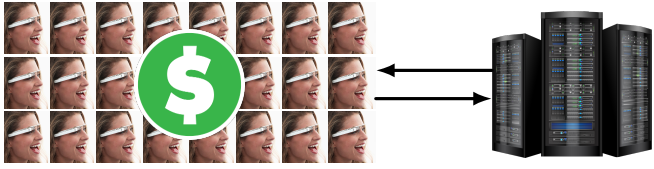

Costly

Studying Human-in-the-Loop Applications

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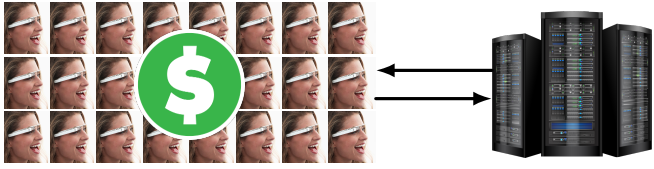
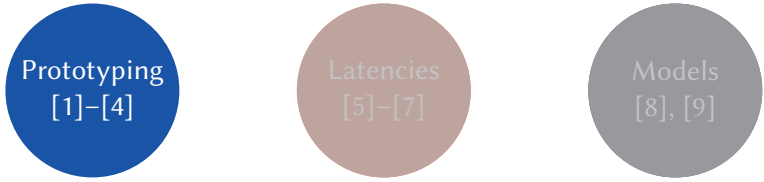
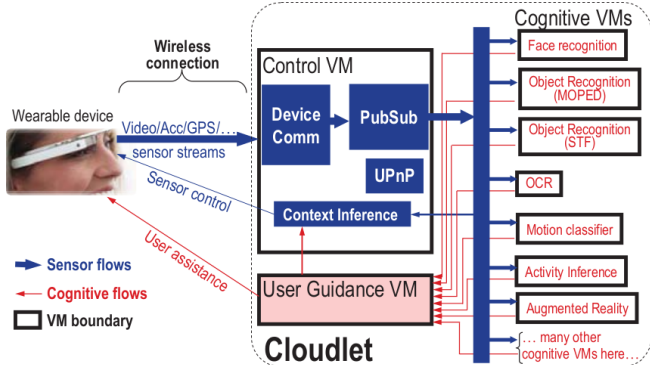


Costly, poor repeatability

Previous & Related Work





Gabriel Platform

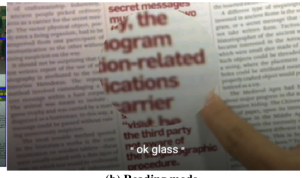
Previous & Related Work

Prototyping [1]–[4]

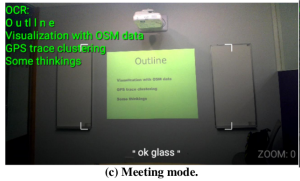
Latencies [5]–[7]

Models [8], [9]

(a) Explore mode.



(b) Reading mode.



(c) Meeting mode.

(d) Driving mode.

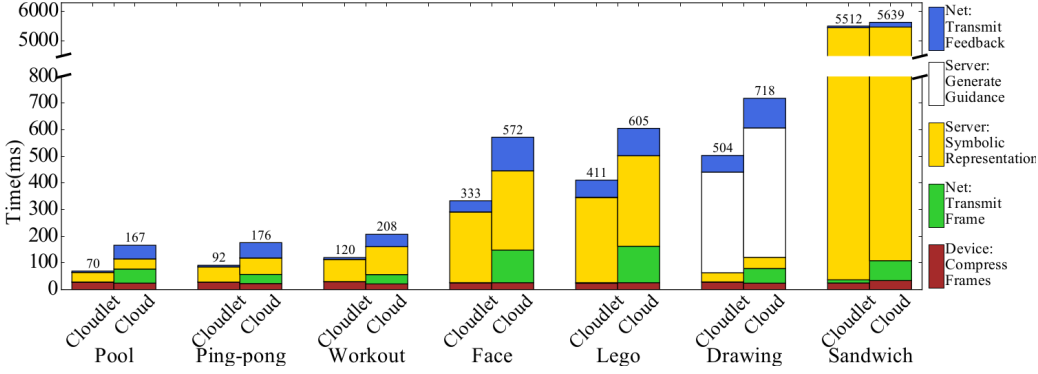
Hyperion Assistant

Previous & Related Work

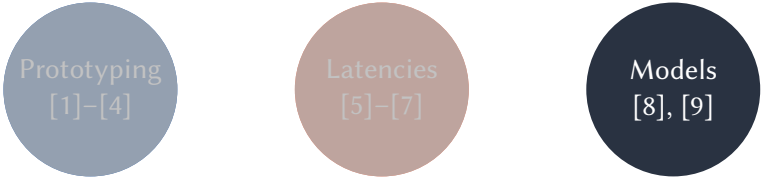
Prototyping [1]–[4]

Latencies [5]–[7]

Models [8], [9]



Previous & Related Work



- H. Al-Zubaidy *et al.*, "Performance of in-network processing for visual analysis in wireless sensor networks," in *Proceedings of the IFIP Networking Conference*, ser. IFIP NETWORKING'15, 2015

- S. Schiessl *et al.*, "Finite-length coding in edge computing scenarios," in *Proceedings of the International Workshop on Smart Antennas*, ser. ITG WSA '17, 2017

Our Contributions

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

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- EdgeDroid: A benchmarking tool-suite.

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- A methodology for benchmarking human-in-the-loop applications.
- EdgeDroid: A benchmarking tool-suite.
- 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?

Benchmarking… what?

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

Answer: Time

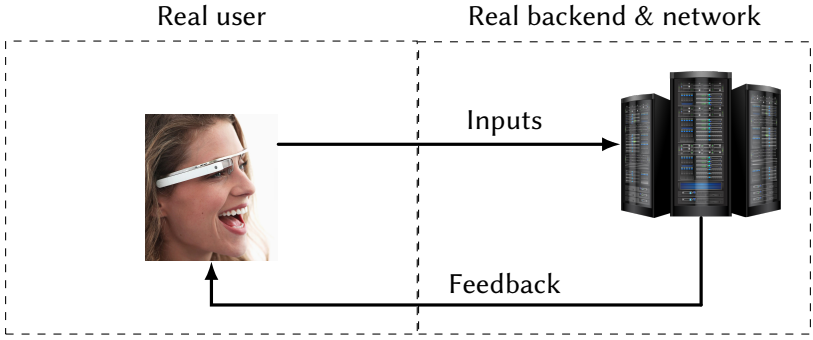
- Latency
- Jitter

Human time-perception is tail-driven…

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

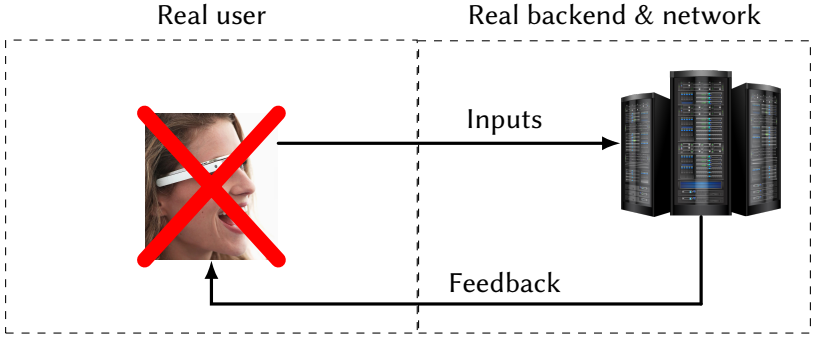
KPIs: Delays (total RTT and segment-wise)

Approach



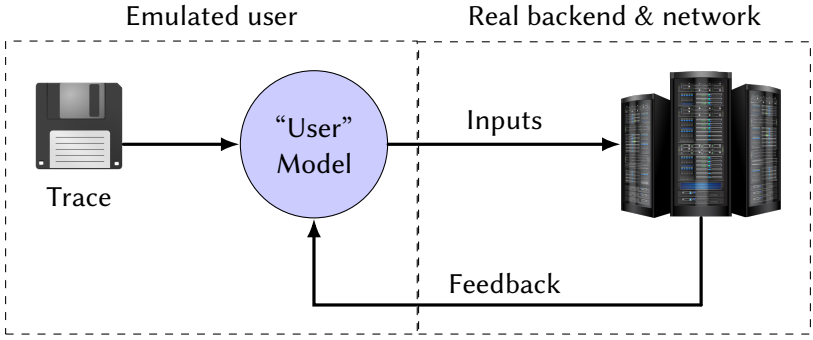
Benchmarking human-in-the-loop applications is HARD

Approach



What if we could do away with the human users?

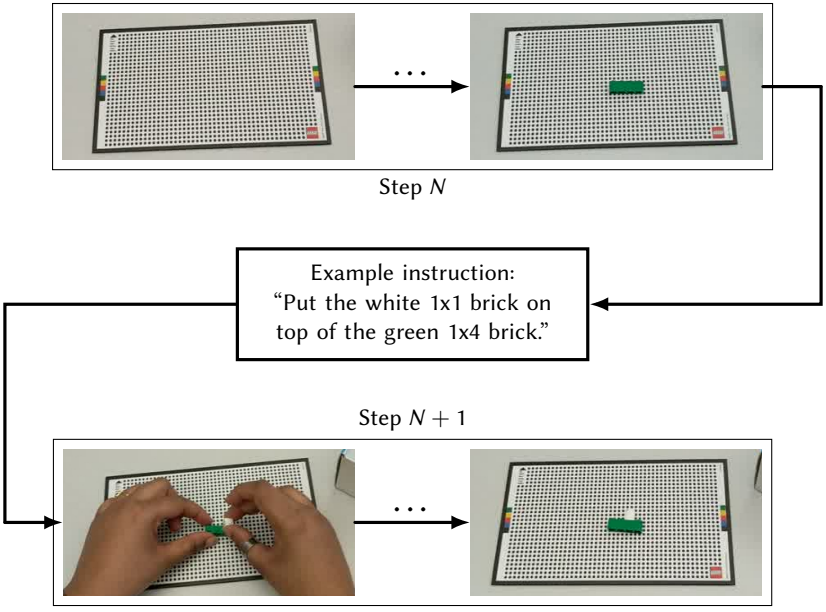
Approach



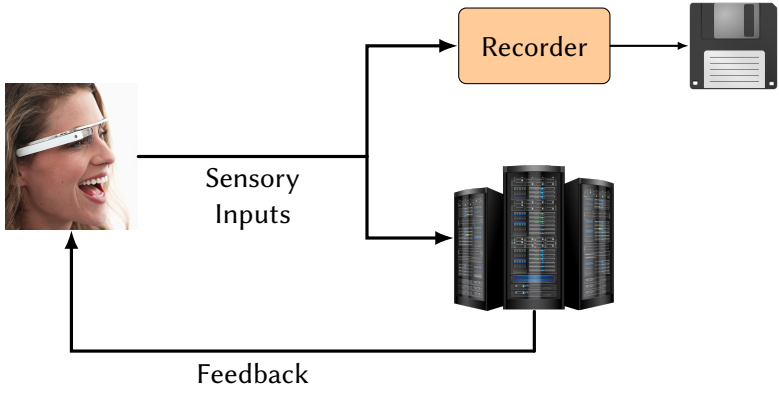
What if we could do away with the human users?

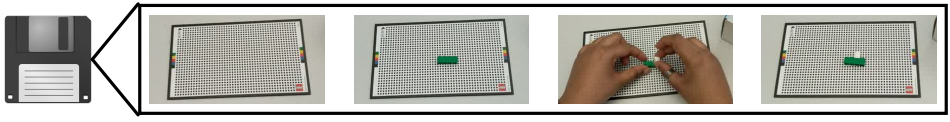
Repeatable, scalable!

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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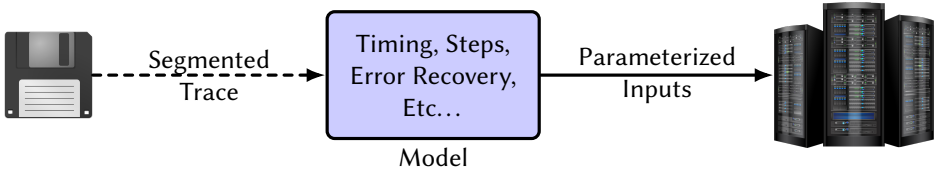
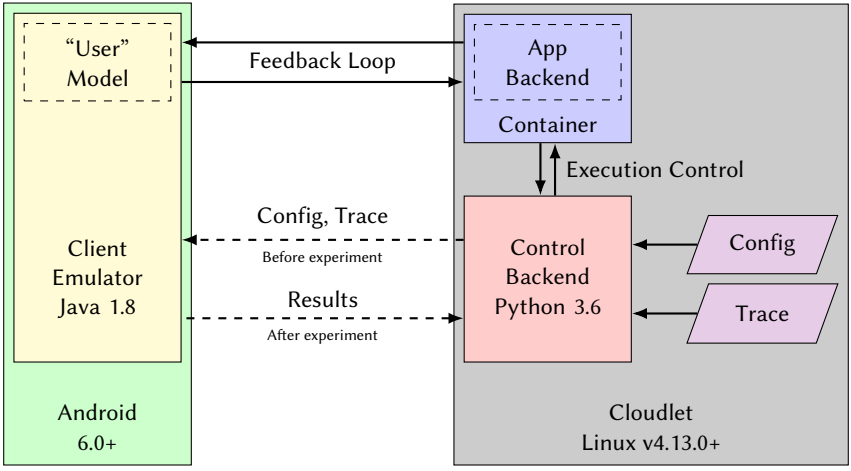
Our Approach

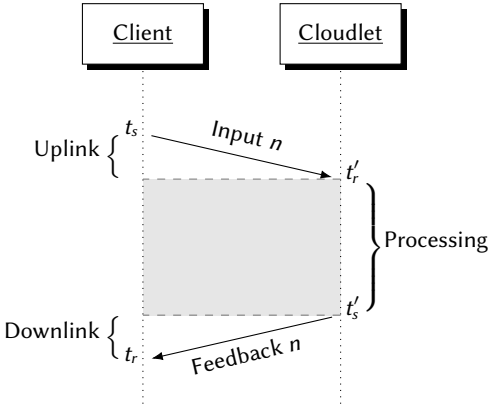
- Segment trace into logical “steps”.
- Controlled replay of steps.



Implementation: EdgeDroid



Timestamping



Clocks are synchronized previous to the experiment.

Timestamps at key points to obtain:

$$\Delta T_{\text{up}} = t'_r - t_s \tag{1}$$
$$\Delta T_{\text{proc}} = t'_s - t'_r \tag{2}$$
$$\Delta T_{\text{down}} = t_r - t'_s \tag{3}$$

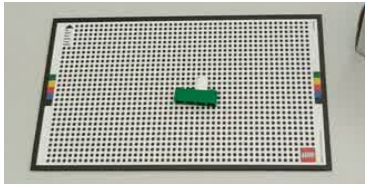
$$\Delta T_{\text{total}} = \Delta T_{\text{up}} + \Delta T_{\text{proc}} + \Delta T_{\text{down}} = t_r - t_s \tag{4}$$

Evaluation

Key purpose:
Demonstrate utility of EdgeDroid.

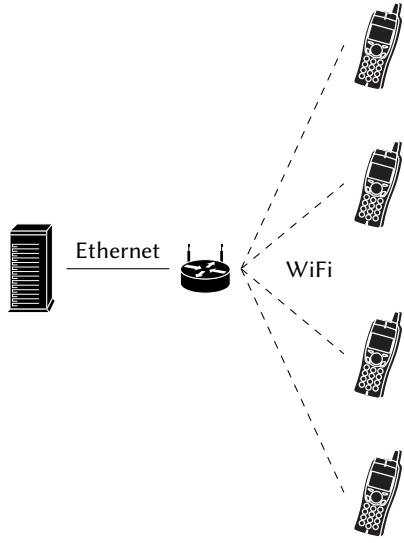
Evaluation: Setup

Application & Scenarios



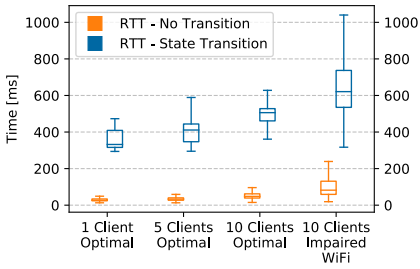
LEGO Assistant

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

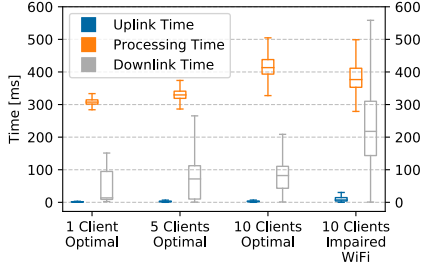


Use Cases

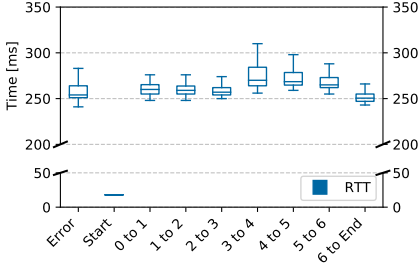
State change vs. no state change.



Times by pipeline segments.



RTT by task step.



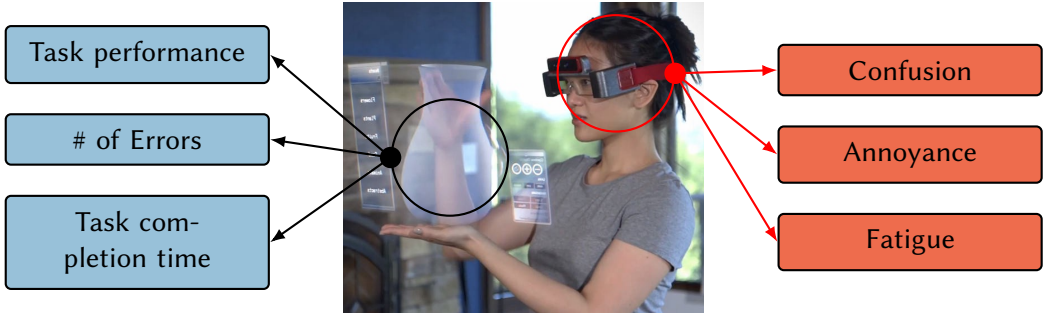
Future Work

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

Characterizing human behavior…

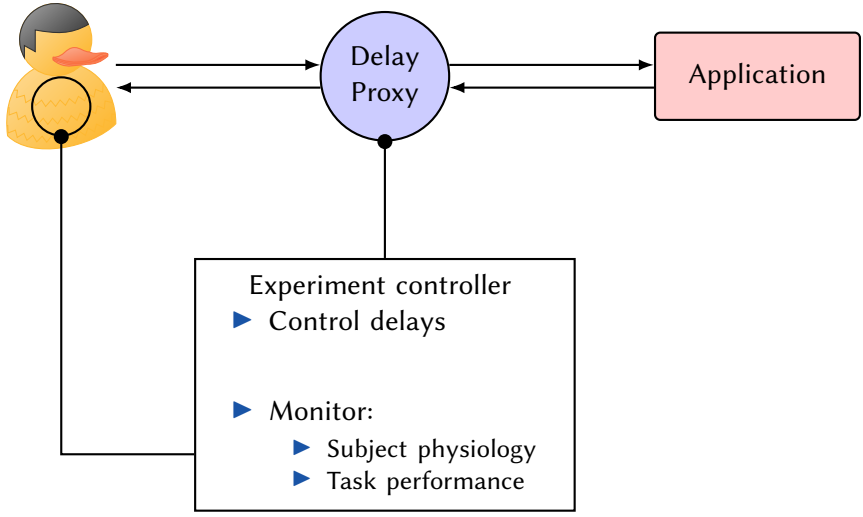
… in the presence of delays in human-in-the-loop applications.

Open research question: how do these delays affect users?



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

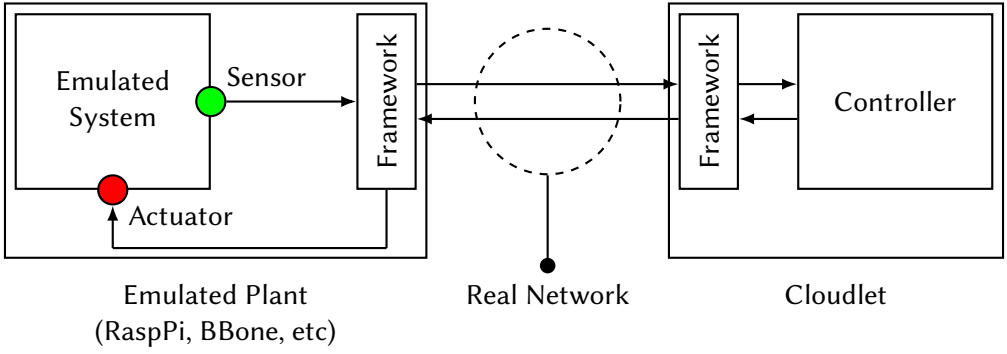
Proposed Experiment Setup



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.

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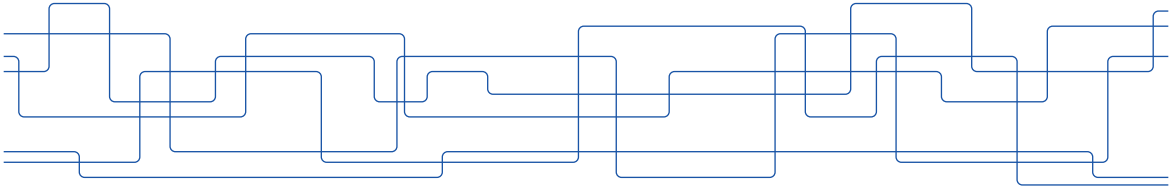
Acknowledgements

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

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

Extra Slides

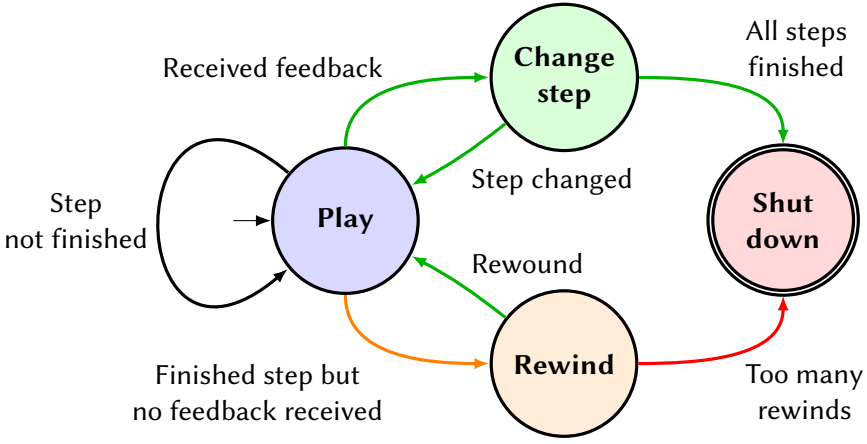


Requirements

- 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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