Real-time analysis of WebGL rendering

University of Trento — Master's degree in Computer Science

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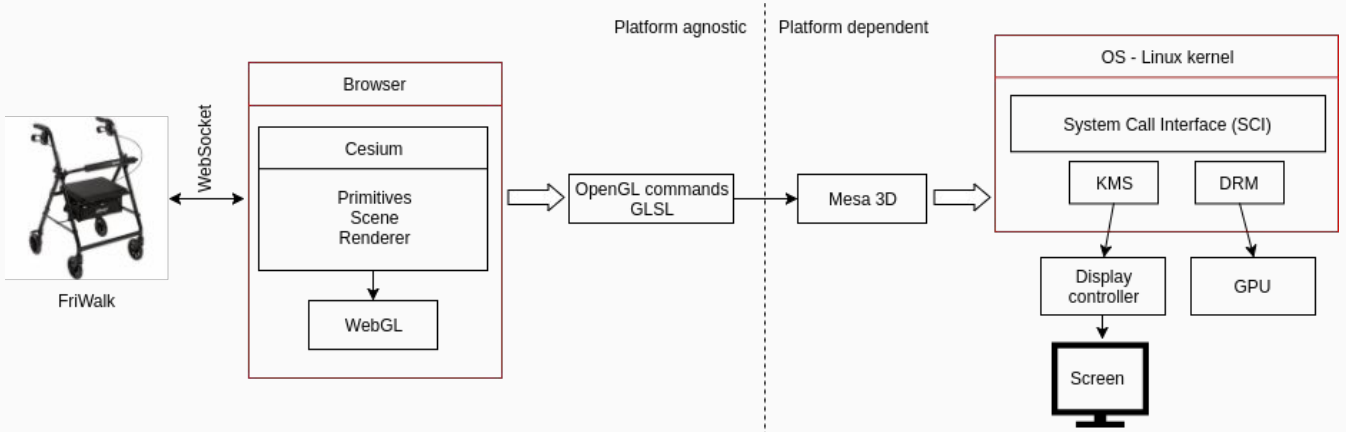
Outline

- System architecture
- Goals
- Background & tools
- Analysis
- Experiments
- Mathematical model
- Results & future work

System architecture



Goals

- Embed 3D navigator into FriWalk [1]
- Analyze layers of graphics pipeline (in Linux)
- Measure timings
- Apply real-time model to web technologies

[1] www.ict-acanto.eu

What is real-time?

- System subject to time constraints
- Correctness depends also on temporal aspects
- Predictable behaviour
- Hard vs. soft

Examples:

- Drive by wire
- Streaming video player

What is WebGL?

- 3D graphics library for the web
- Based on OpenGL ES
- Hardware-accelerated
- Cross-platform
- Supported by all major browsers

Examples:

- Google Maps
- Unity 3D

Tools

- Google Chrome browser
- Web Tracing Framework (WTF)
- Chrome’s internal Trace Event Profiler

Analysis

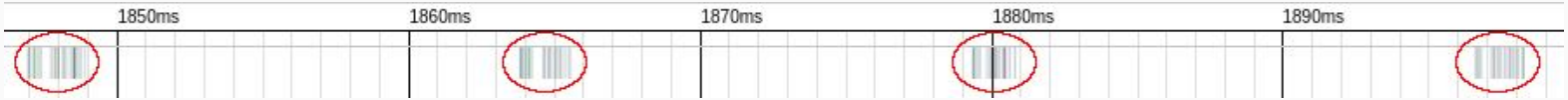
- Macro-to-micro approach
- Increase focus on data
- Different scenarios
  - Complete
  - Camera only
  - Redraw
  - No map

Experiments
First measurements — WTF

- Code instrumentation
- Measure only **response time**

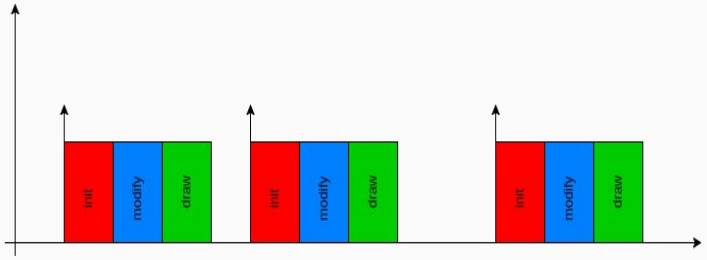
```
response_time = computation_time + interference
```

- Graphics primitives groups
- Always start with `bindBuffer`

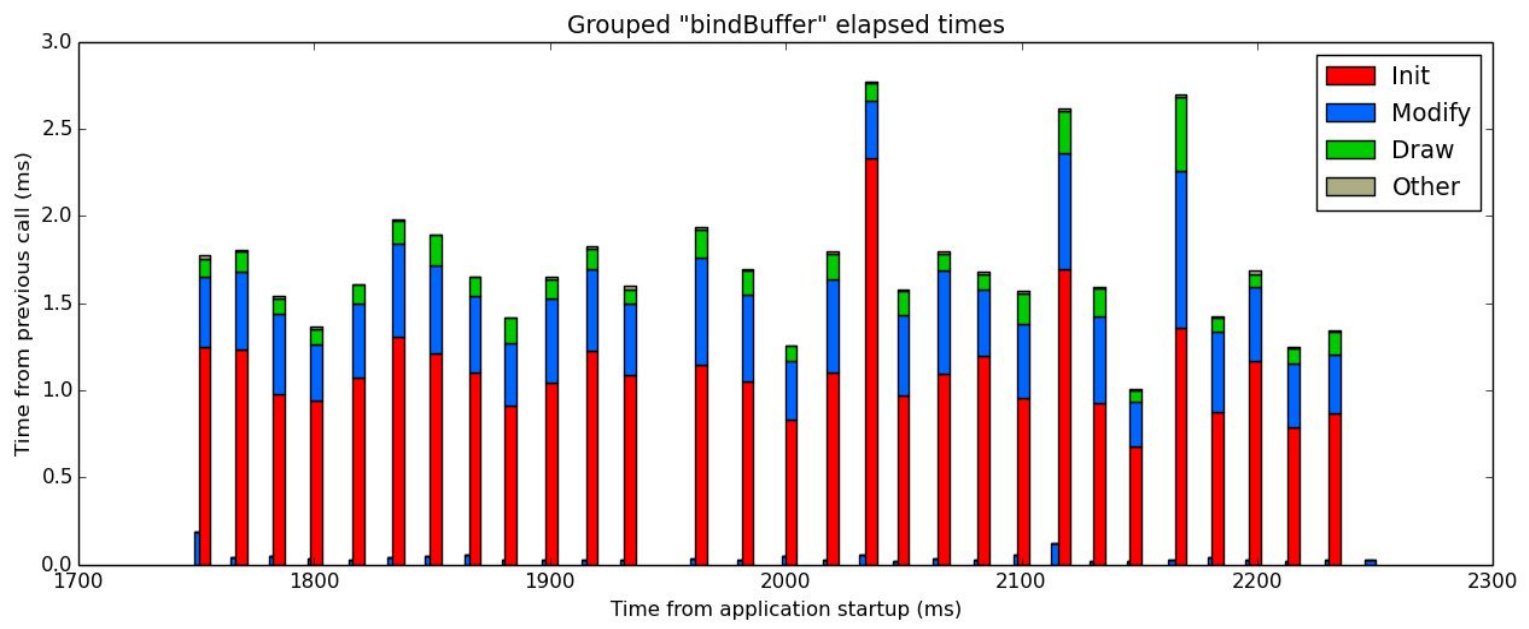


Experiments
First measurements cont’d

- High-level view
- Identify 3 main groups of functions
  - Initialization/load data
  - Modify data
  - Display/draw



Response time grouped by scope



Experiments
Fine-grained model — Trace Event Profiler

- Focus on “display/draw” group
  - Trace Chrome’s GPU process from server side
- Exact **computation time**
  - *tdur*: thread clock duration of complete events (in µs)
- Higher resolution
  - WTF: ± 0.5 ms
  - Trace Event Profiler: ±1 µs

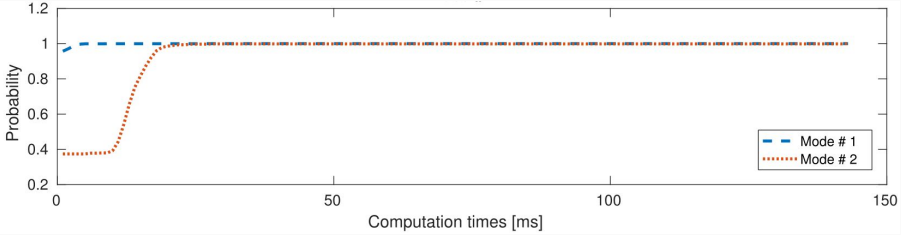
Mathematical model

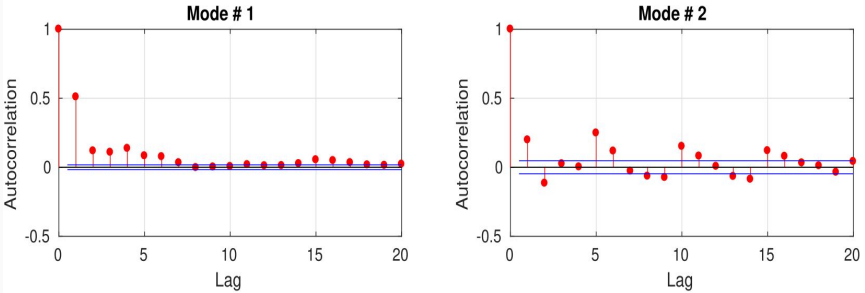
- **Markov Computation Time Model** [2]
  - When i.i.d. assumption does not hold
  - No unique computation time distribution
- The system
  - *N* modes
  - Each state represented by its own distribution function
  - Transition matrix between states

[2] Frías, B. Villalba, et al. "Probabilistic real–time guarantees: There is life beyond the iid assumption." Real-Time and Embedded Technology and Applications Symposium (RTAS), 2017 IEEE. 2017

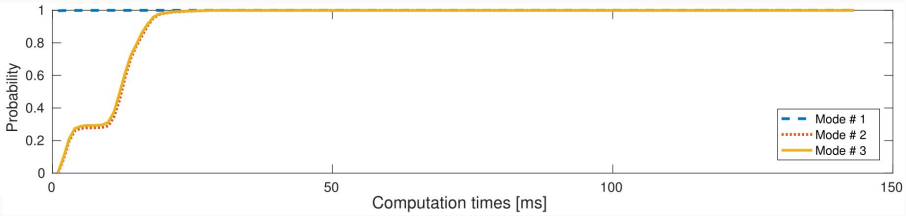
Why exactly 2 states?

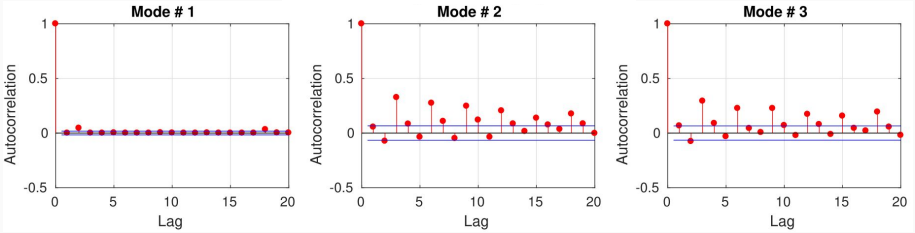
2 states



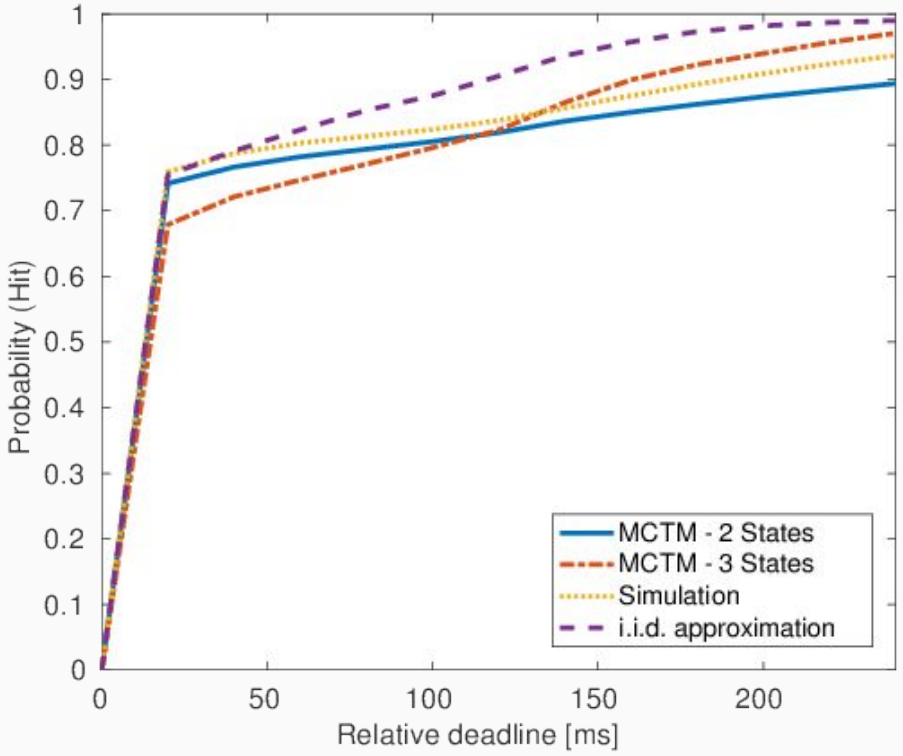


3 states





Deadline hit probability



Results

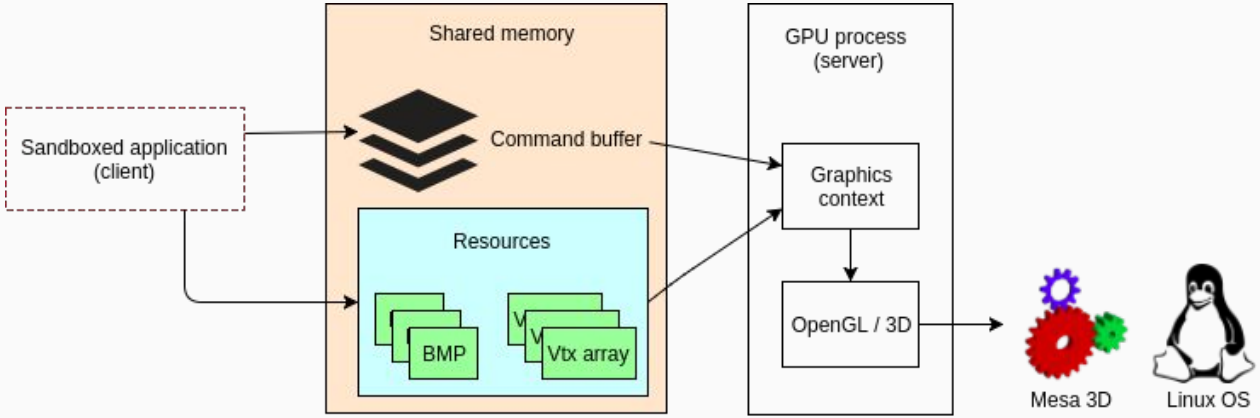
- Model successfully applied to test application
- MCTM with 2 states
- Uncorrelated computation time between states
- Always conservative w.r.t. simulation

Future work:

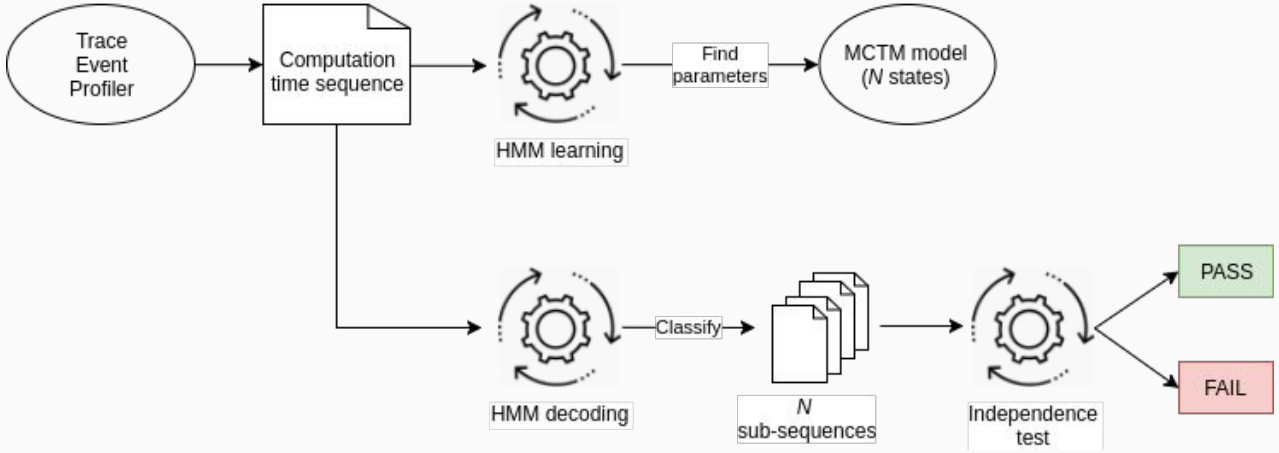
- Run analysis on FriWalk’s specific hardware
- Per-frame study

Thank you for your attention

Google Chrome GPU process



Model’s workflow



Deadline hit comparison