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A Comprehensive End-to-End Lag Model for Online and Cloud Video Gaming

Florian Metzger, Albert Rafetseder, Christian Schwartz ■ 2016/08/29

Modeling of Adaptive Systems

https://www.mas.wiwi.uni-due.de/en

CS:GO gameplay at 30fps (normally played at 120+)

clip extracted from https://www.youtube.com/watch?v=02I5vVxlJhU

same clip at 6fps

clip extracted from https://www.youtube.com/watch?v=02I5vVx1JhU

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  - Wrong choice of metrics to detect influence of lag (e.g. time-scale wise)

  - Focus just on network delay, not full E2E lag

  - Observation periods too short

  - No understanding of core gameplay mechanics

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- Many interlocked mechanics in play, we need to understand their effects!

$\Rightarrow$ Set up a small sim to to get some rough numbers

Framerate and Frametime

Rate at which the game renders distinct images. Frametime is the time between two such images.

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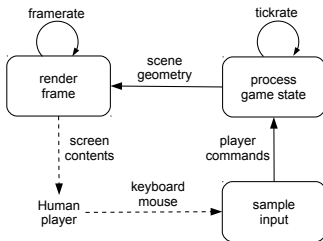
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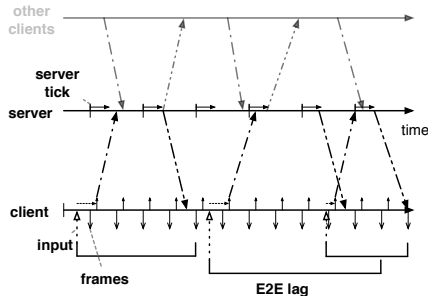Rate at which the server in a client/server-game updates its game simulation state.
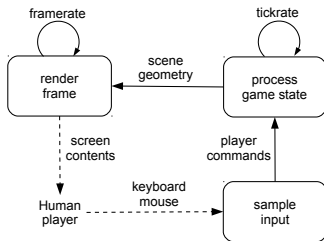
Framerate constraints:

- Motion perception in video: Based on principle of apparent motion according to [Wer12], starting at a min. frame rate of 16 Hz

- But framerate and tickrate are also governing factors for input latency

- Common game frame rates:
  30 Hz, 60 Hz, 120 Hz, 144 Hz

- Perceived delay and delay variation between input action and visible reaction

- Caused by various latency sources, e.g. network QoS, I/O devices, game engine, game mechanics

- But also through the interplay of framerate and tickrate

- Examples of tickrates in c/s-games: CS:GO 64 Hz to 128 Hz; Dota 2 30 Hz; Overwatch 60 Hz

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http://blog.logicalincrements.com/2015/04/does-fps-matter-decide-for-yourself/

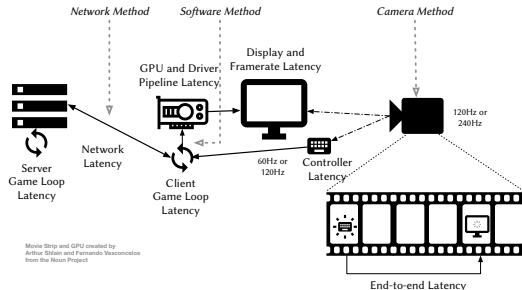- Lag affects reaction and timings, gameplay, player performance

⇒ Potentially largest **QoE** influencer

- Every game, every gameplay action, can behave differently under lag

- Different viewpoints to observe lag, but full E2E lag can only be captured externally

- Lag affects reaction and timings, gameplay, player performance
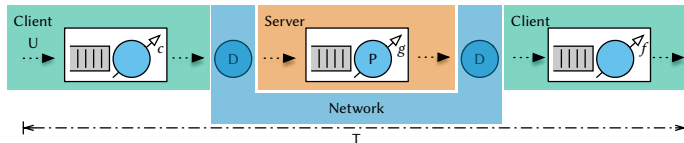⇒ Potentially largest **QoE** influencer
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Network Method   *Software Method*   *Camera Method*

GPU and Driver,
Pipeline Latency

Display and
Framerate Latency

120Hz or
240Hz

Server
Game Loop
Latency

Network
Latency

Client
Game Loop
Latency

60Hz or
120Hz

Controller
Latency

Movie Strip and GPU created by
Arthur Shlain and Fernando Vasconcelos
from the Noun Project

End-to-end Latency

- Lag sources modeled in a queuing system

- Goal: investigate lag sources not typically attributed to lag

- Especially: frame- and tickrate; but also: message rates, input and display devices

- Frame- and tickrate modeled as independently clocked processes

[1]`https://github.com/mas-ude/onlinegame-lag-sim`

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- Frame- and tickrate modeled as independently clocked processes

- Implemented as R simulation[1]

- Evaluated for several scenarios and parameter combinations

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Model Limitations and Caveats

Lag-Concealing Features in Games

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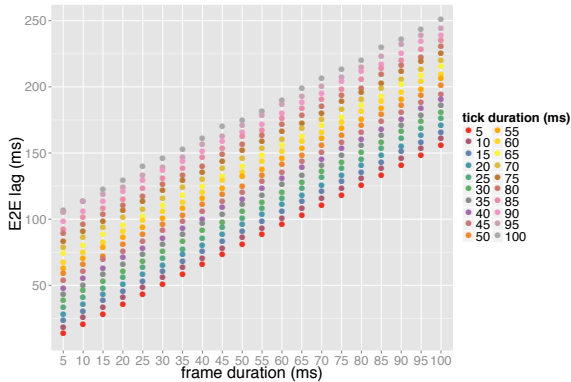DUISBURG
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Examples of features that can reduce lag impact in games, but are not considered in the model and sim:

- Immediate visualization and output of object actions through client-side **prediction** (e.g. player movement) without waiting for authoritative answer
    - Roll back action if prediction wrong

- **Interpolate** motion between consecutive game simulation snapshots from the server, or extrapolate from last two snapshots

- Lag **compensation** by doing hit detection on object positions slightly in the past
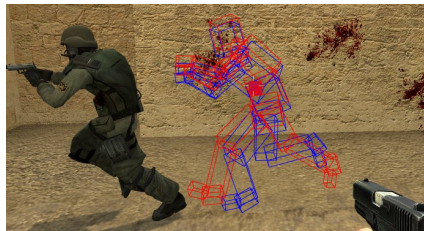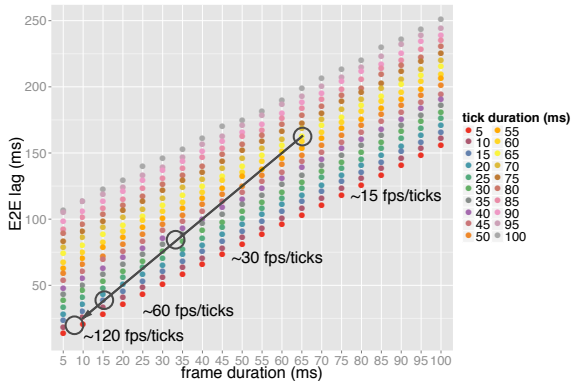

developer.valvesoftware.com/wiki/Lag_compensation

Locally running C/S-game, no network interactions involved, average of 1000 runs.


(Note 16.67 ms frame duration $\hat{=}$ 60 Hz framerate)

Local Game Simulation

A.K.A.: Best Case Lag Scenario

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Locally running C/S-game, no network interactions involved, average of 1000 runs.

Linear decrease of E2E lag; 50 ms less going from 30 to 60.

Local Game Simulation

A.K.A.: Best Case Lag Scenario

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Locally running C/S-game, no network interactions involved, average of 1000 runs.
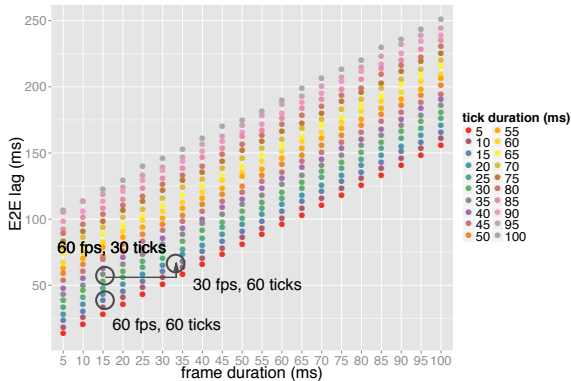
Bigger impact of framerate than tickrate!

Networked game at 10 Hz to 200 Hz frame- and tickrates;

median of 1000 rounds for each bar; 40 ms base network RTT.
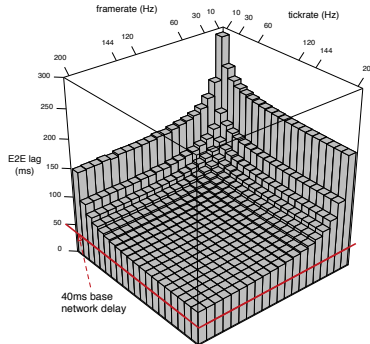
Network is not the main source of lag at low frame-/tickrates!

Similar to networked C/S but with added video en-/decoding delay and frame transmission times

(Vertical line denotes average base networking and en-/decoding delay)
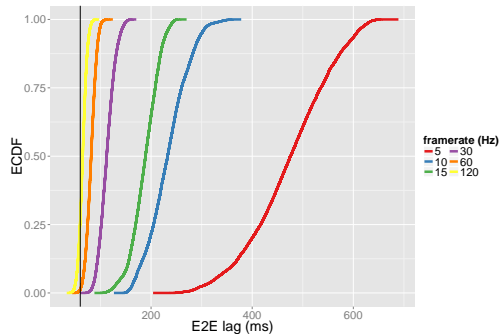
Large E2E lag and (more importantly) broad spread of lag values

$\Rightarrow$ input actions are experienced as "stuttering"

- Simplified simulation of typical gaming scenarios

- Complex scenario due to interactivity and diversity of video games

- Reexamine and focus on framerates as a large QoE factor

- Larger influence of framerates than generally accepted

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In the future:

- More extensive simulation setup with more influence factors
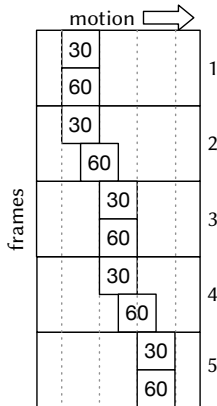
- Derive guidelines for future user studies

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Questions?

https://github.com/mas-ude/onlinegame-lag-sim

Contact: florian.metzger@uni-due.de

Key fingerprint: C98A 32B7 554F C5CC 4E5A 60FB 1CE5 B541 7B20 99C7

http://hugelol.com/lol/364250
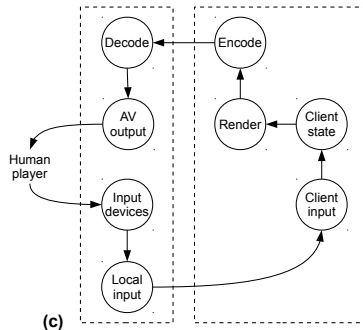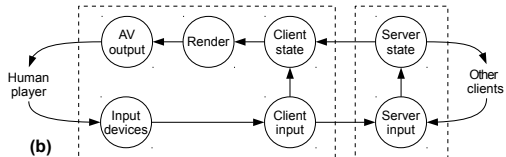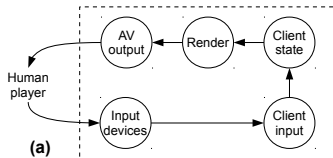
(a) local game, *(b)* networked game, *(c)* cloud game

Command message rates and client update rates can differ from server tickrates

Video Game	Tickrate
CS: GO	Configurable 64 Hz/128 Hz
Battlefield 4	Configurable 60 Hz/120 Hz; previously 30 Hz with 10 Hz for state outside of close proximity
Minecraft	max. 20 Hz
League of Legends	30 Hz
Dota 2	30 Hz
StarCraft II	supposedly either 16 Hz or 32 Hz
Eve Online	1 Hz
Overwatch	60 (client update rate previously was 20)

Note: Values are considered to be unofficial and may be unreliable

G. Armitage. "An experimental estimation of latency sensitivity in multiplayer Quake 3."
In: *Networks, 2003. ICON2003. The 11th IEEE International Conference on.* Sept. 2003,
pp. 137–141.

Michael Bredel and Markus Fidler. "A Measurement Study Regarding Quality of Service and
Its Impact on Multiplayer Online Games."
In: *Proceedings of the 9th Annual Workshop on Network and Systems Support for Games.*
NetGames '10. Taipei, Taiwan: IEEE Press, 2010, 1:1–1:6. ISBN: 978-1-4244-8355-6.

Mark Claypool and Kajal Claypool. "Latency and Player Actions in Online Games."
In: *Commun. ACM* 49.11 (Nov. 2006), pp. 40–45. ISSN: 0001-0782.

KajalT. Claypool and Mark Claypool.
"On frame rate and player performance in first person shooter games." English.
In: *Multimedia Systems* 13.1 (2007), pp. 3–17. ISSN: 0942-4962.

📄 Kuan-Ta Chen, Polly Huang, and Chin-Laung Lei.

"Effect of Network Quality on Player Departure Behavior in Online Games."

In: *Parallel and Distributed Systems, IEEE Transactions on* 20.5 (May 2009), pp. 593–606.

ISSN: 1045-9219.

📄 V. Clincy and B. Wilgor.

"Subjective Evaluation of Latency and Packet Loss in a Cloud-Based Game."

In: *Information Technology: New Generations (ITNG), 2013 Tenth International Conference on*.

Apr. 2013, pp. 473–476.

📄 Zenja Ivkovic, Ian Stavness, Carl Gutwin, and Steven Sutcliffe. "Quantifying and Mitigating
the Negative Effects of Local Latencies on Aiming in 3D Shooter Games."

In: *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems*.

CHI '15. Seoul, Republic of Korea: ACM, 2015, pp. 135–144. ISBN: 978-1-4503-3145-6.

📄 M. Jarschel, D. Schlosser, S. Scheuring, and T. Hossfeld.

"An Evaluation of QoE in Cloud Gaming Based on Subjective Tests." In: *Innovative Mobile and Internet Services in Ubiquitous Computing (IMIS), 2011 Fifth International Conference on.* June 2011, pp. 330–335.

📄 Florian Metzger, Albert Rafetseder, Christian Schwartz, and Tobias Hoßfeld.

"Games and Frames: A Strange Tale of QoE Studies."

In: *Proceedings of the 8th International Conference on Quality of Multimedia Experience.* QoMEX 2016. June 2016.

📄 Sebastian Möller et al.

"Towards a New ITU-T Recommendation for Subjective Methods Evaluating Gaming QoE." In: (2015).

M. Ries, P. Svoboda, and M. Rupp.

"Empirical study of subjective quality for Massive Multiplayer Games."

In: *Systems, Signals and Image Processing, 2008. IWSSIP 2008. 15th International Conference on.*

June 2008, pp. 181–184.

Colin Ware and Ravin Balakrishnan.

"Reaching for Objects in VR Displays: Lag and Frame Rate."

In: *ACM Trans. Comput.-Hum. Interact.* 1.4 (Dec. 1994), pp. 331–356. ISSN: 1073-0516.

Max Wertheimer. "Experimentelle Studien über das Sehen von Bewegung." PhD thesis. 1912.