Ph.D. Dissertation Defense

The Impact of Latency on Players in First-person Shooter Games

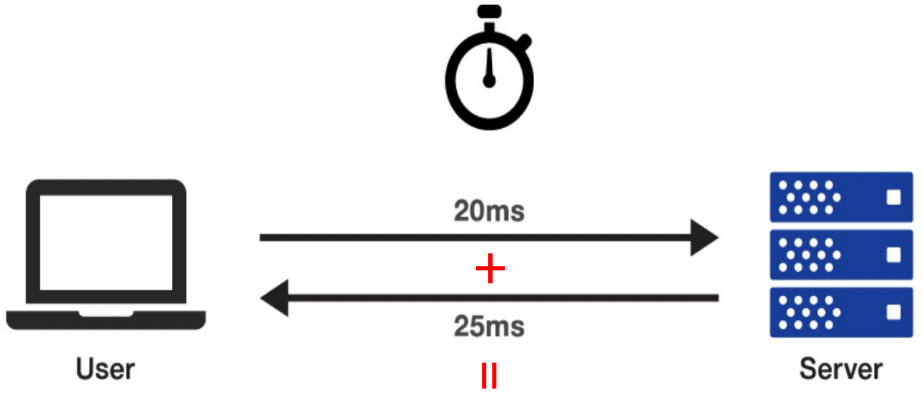
Student:
Shengmei Liu

Committee:
Prof. Mark Claypool, Worcester Polytechnic Institute
Prof. Carl Gutwin, University of Saskatchewan
Prof. Lane Harrison, Worcester Polytechnic Institute
Doc. Jamie Sherman, Atlassian

Worcester Polytechnic Institute

Latency

Local latency



=

Network latency

Performance

Latency and gamers

[Liu et al., 2021]

Motivation

Games

.....

Weapons

.....

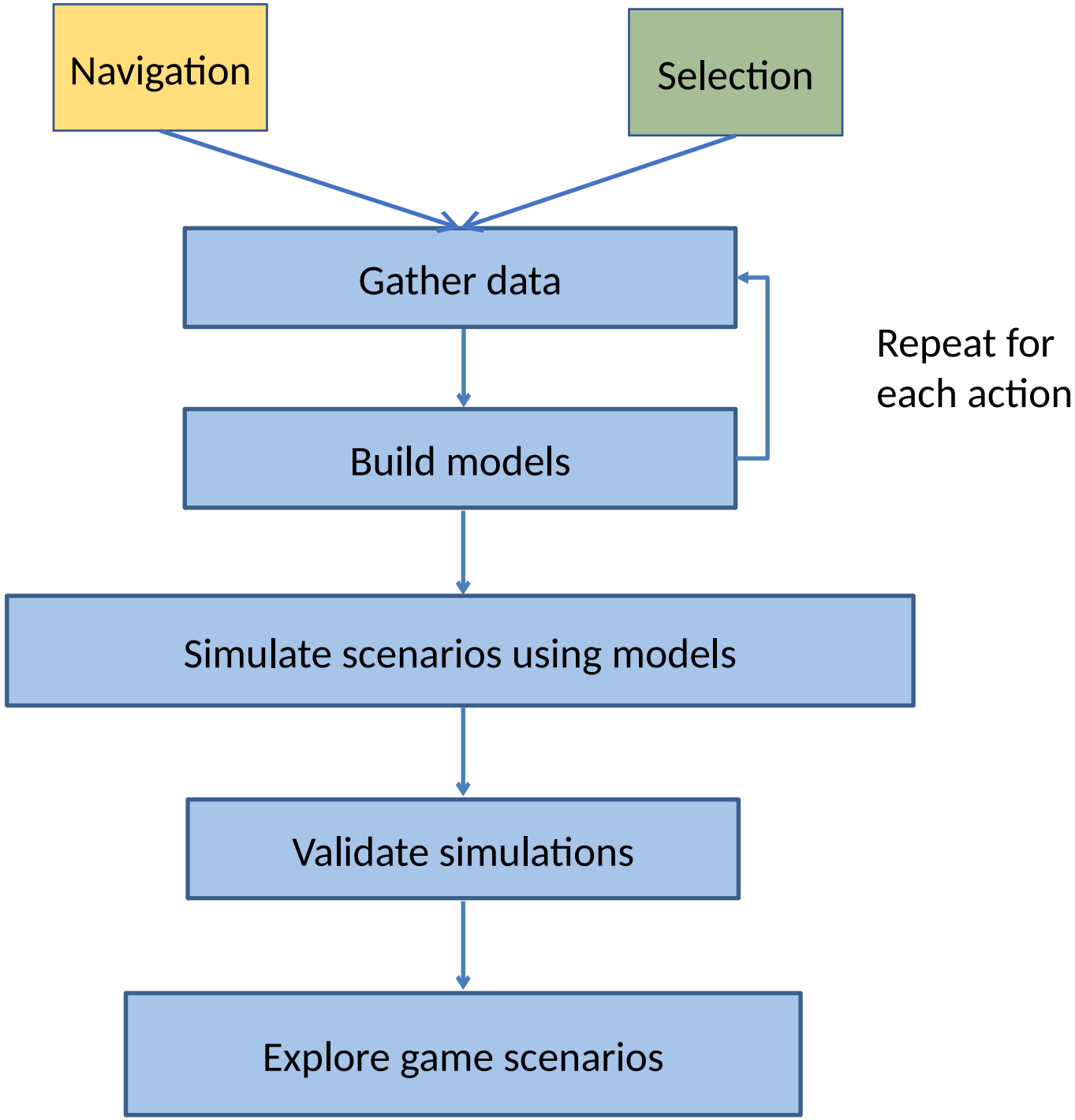
Maps

.....

Skills

.....

Approach


Navigation
Selection
Gather data
Build models
Repeat for each action
Simulate scenarios using models
Validate simulations
Explore game scenarios

Related publications

Navigation, CHI 2022

Selection, MMSys 2023

CSGO local latency, CHI 2021

CSGO network latency, QoMEX 2021

Gaming actions - Selection

Gaming actions - First-person navigation

Related work – Gaming actions

Selection:

[JT14, CER17, LG18, LG19]

- Evaluated latency on 2D selection tasks
- Latency has significant impact on player performance

Navigation:

[Dru71, AZ97, AZ99, AZ01, ZAW04, KGS07, KS16]

- Proposed or enriched steering law
- Steering law can accurately predict player performance

Related work – Latency

Latency:
[PW02, Arm03, QML+04, DWW05, FRS05, CC06, CC07, AJG+13, HCW+14, ISGS15, HFPG16, CER17, ERC18, LG18, LG19, LKS+21b]

- Studies on specific game or game tasks
- Significant impact on players

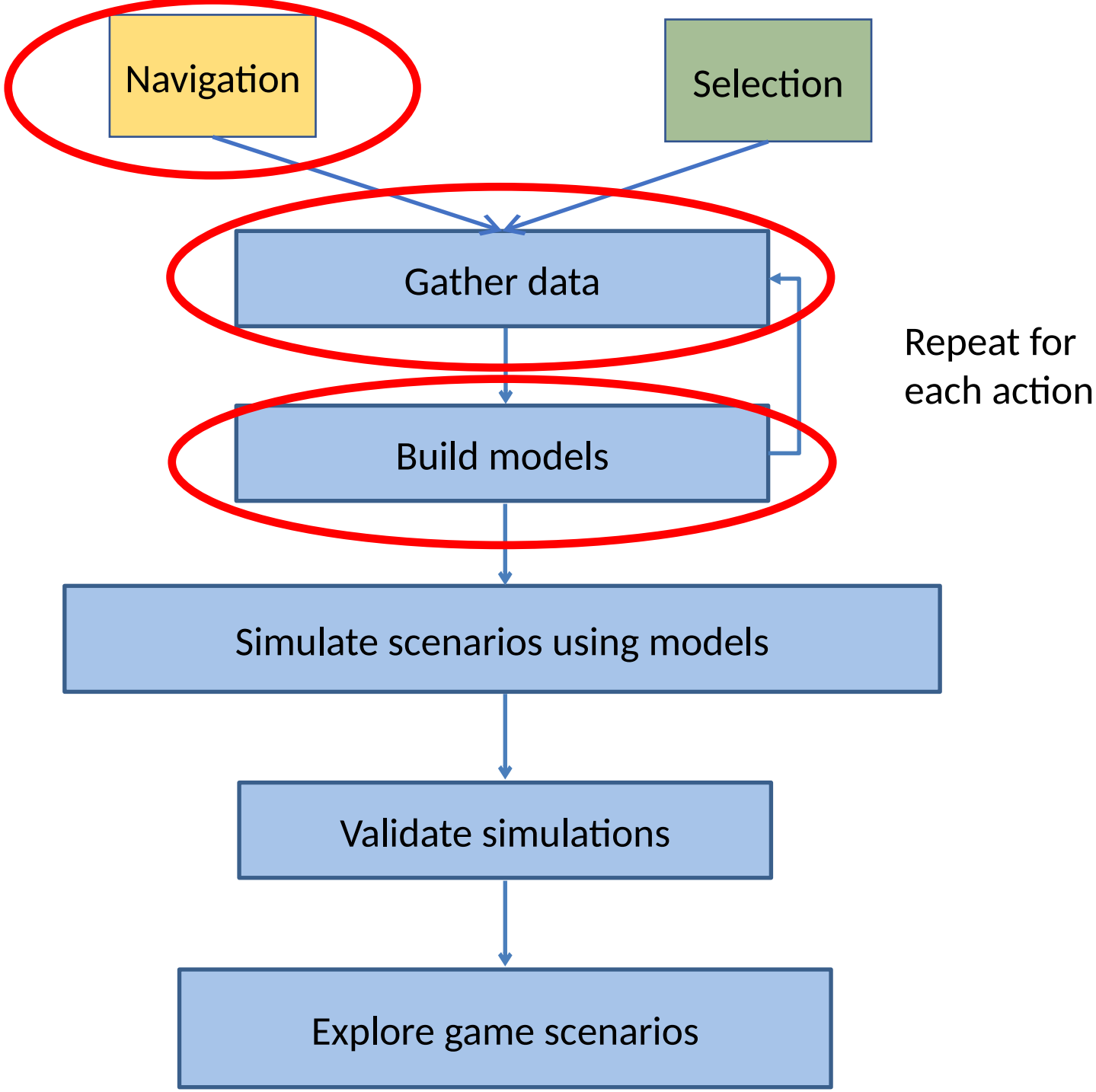
Related work – Latency compensation techniques

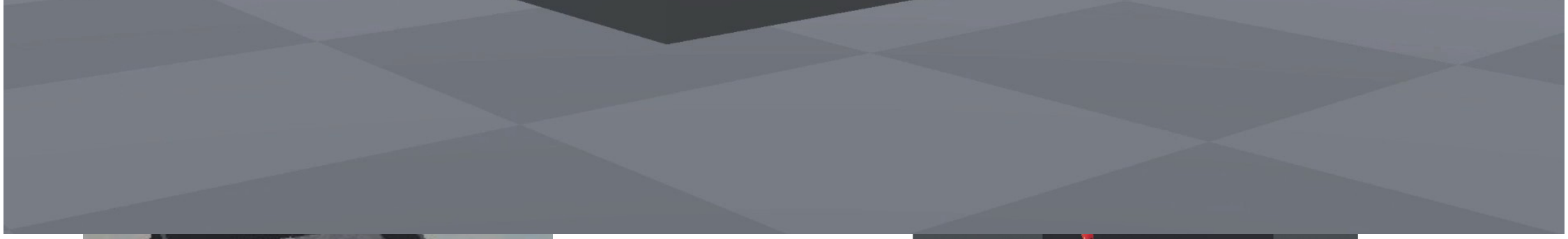
Time warp & Self-prediction :

[Jef85, Mau00b, Mau00a, WO00, MVHE04, JSB05, SK05, BK06, BSB06, CCC+07, TAS07, SGG10, LC15, LC17, LSGH17, AMC18, LC18, SC19]

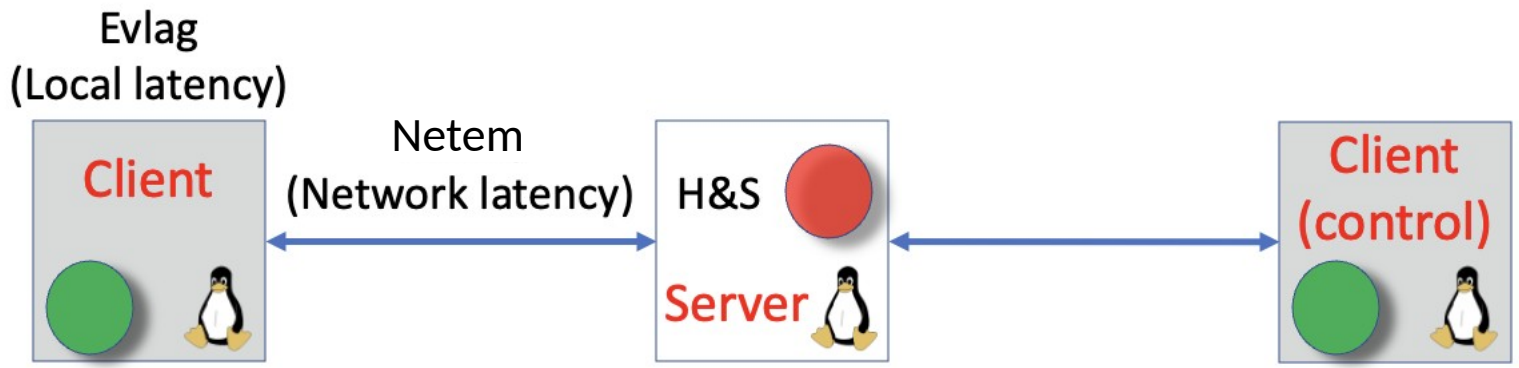
- Proposed, enriched and/or evaluated time warp
- Both techniques can significantly improve player performance with latency

Approach


Navigation
Selection
Gather data
Build models
Repeat for each action
Simulate scenarios using models
Validate simulations
Explore game scenarios



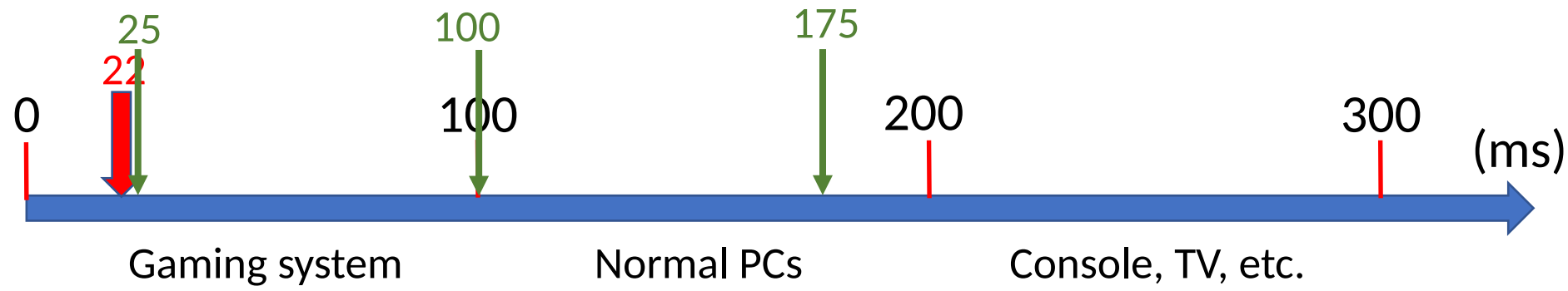
- Client-server architecture



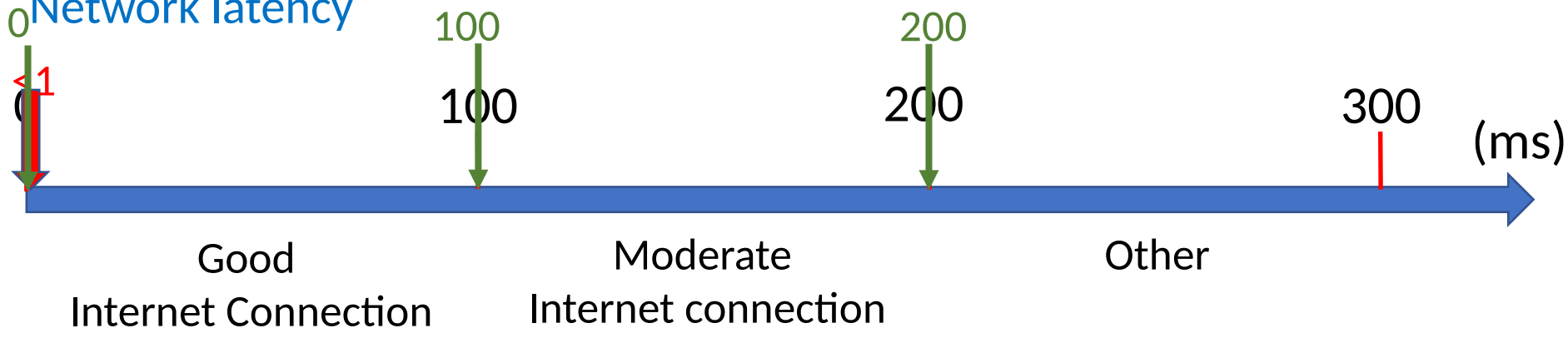
- Consistent opponent (me)

Navigation user study

- Local latency



- Network latency



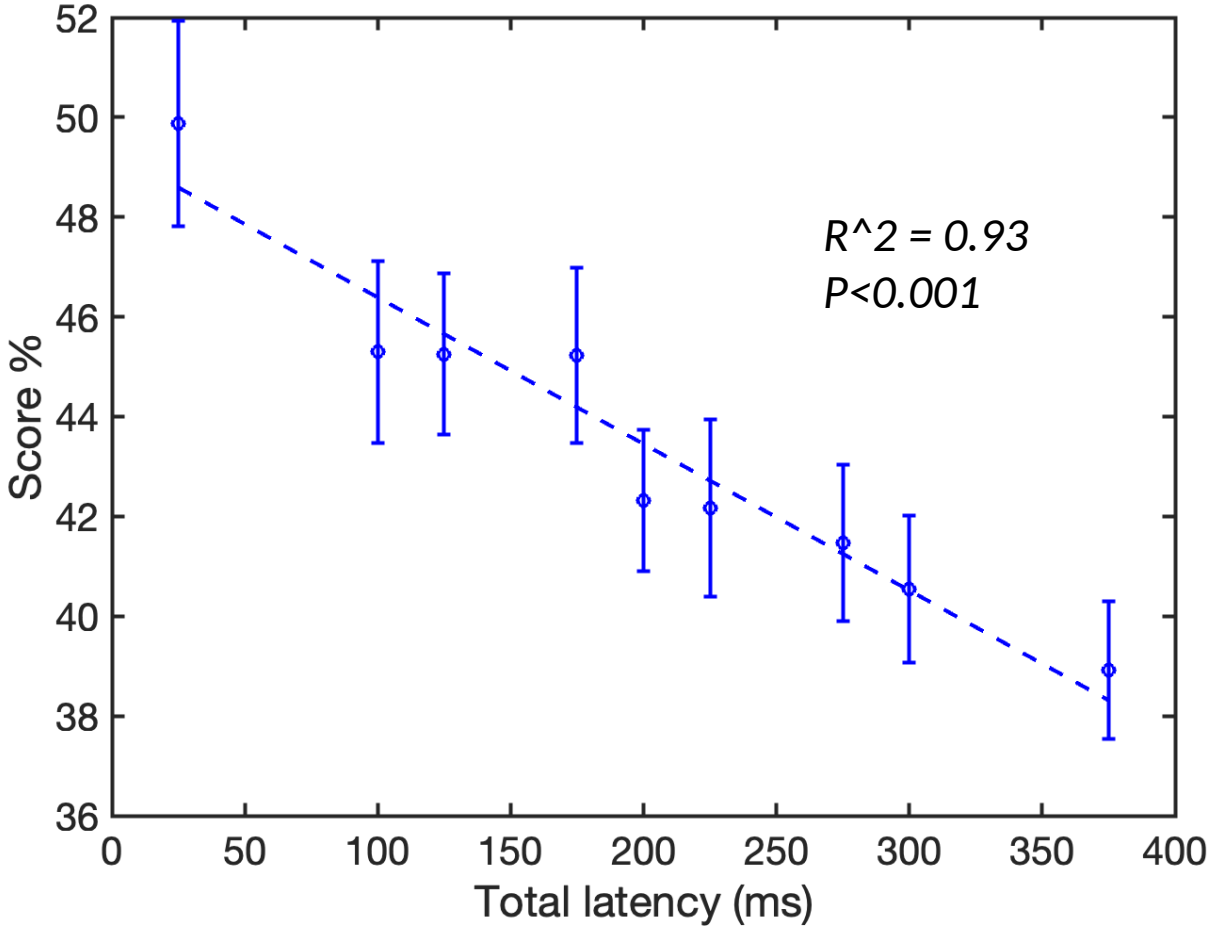
3 trials for each latency → 27 rounds
→ 40 sec per round → ~ 30 min total

Navigation demographics

- 30 users

Users	Age (yrs)	Gender	Gaming per week (hours)	Game Self-rating	FPS Self-rating	Reaction-time (ms)
30	23.1 (4.0)	26 ♂4 ♀	10.4 (8.3)	3.4 (1.1)	3.1 (1.0)	227.2 (40.0)

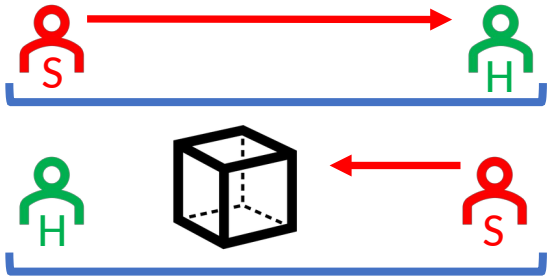
Navigation results

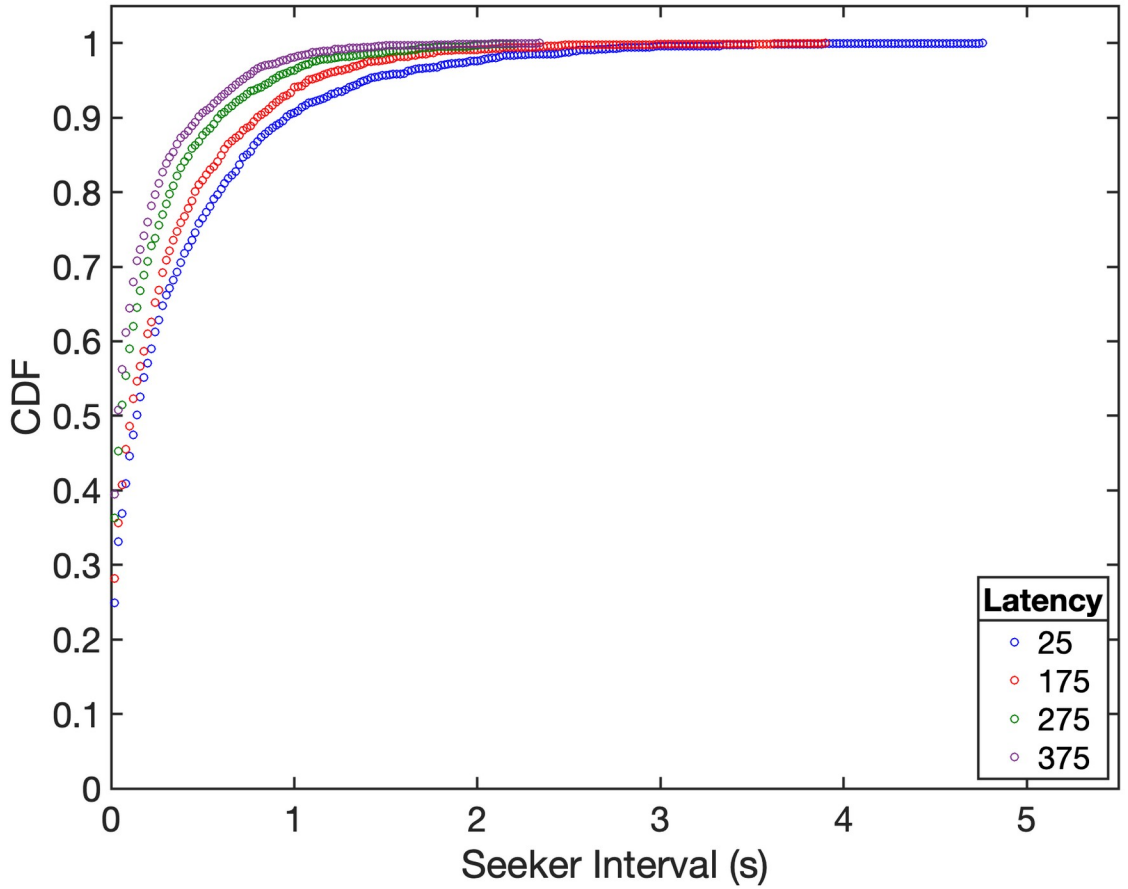


A decrease in total latency by 100 ms improves player performance by 11 percent

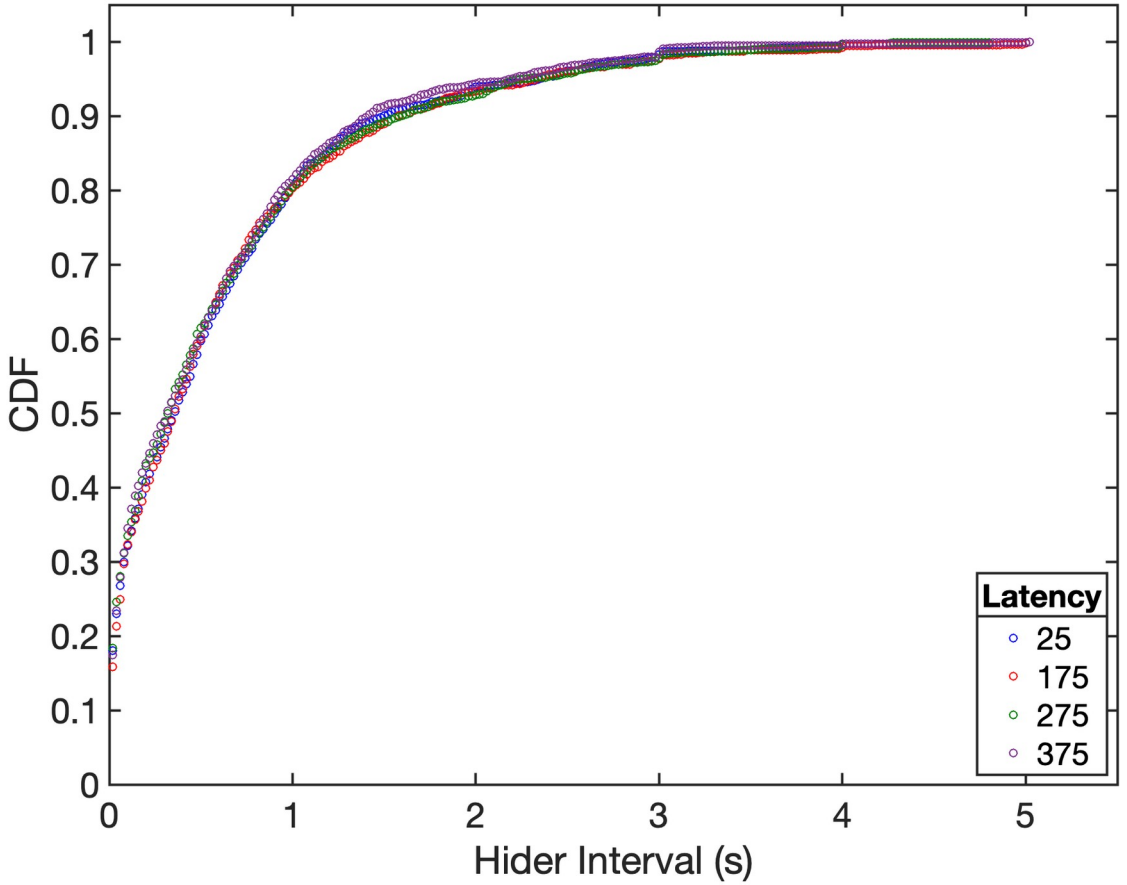
Navigation distributions

-Seeker intervals. hider intervals





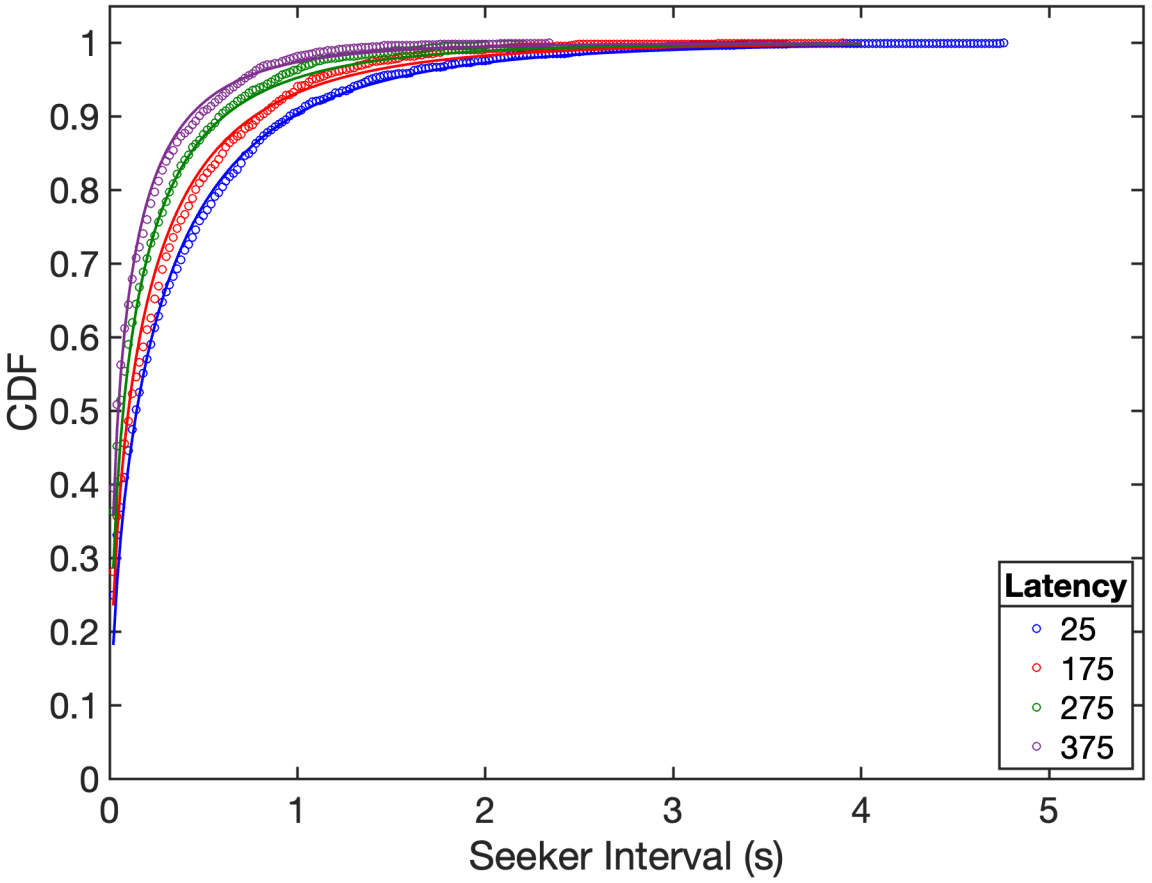
- Exponential
- Stretched exponential



- Weibull
- Pareto
- Log-gamma

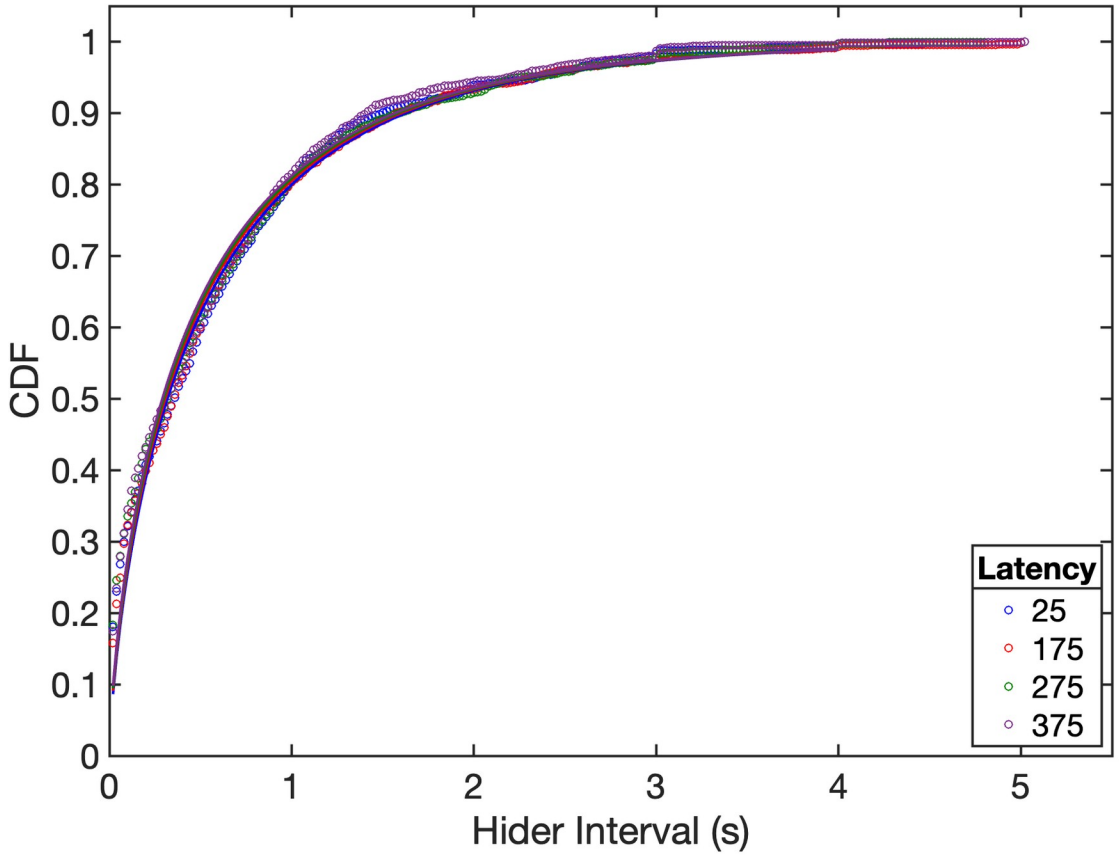
Navigation models

-Seeker intervals, hider



$$p = 1 - exp(-\frac{in\_sight\_window}{a \times (loc\_lat + net\_lat) + b})^{c \times (loc\_lat + net\_lat) + d} + e$$

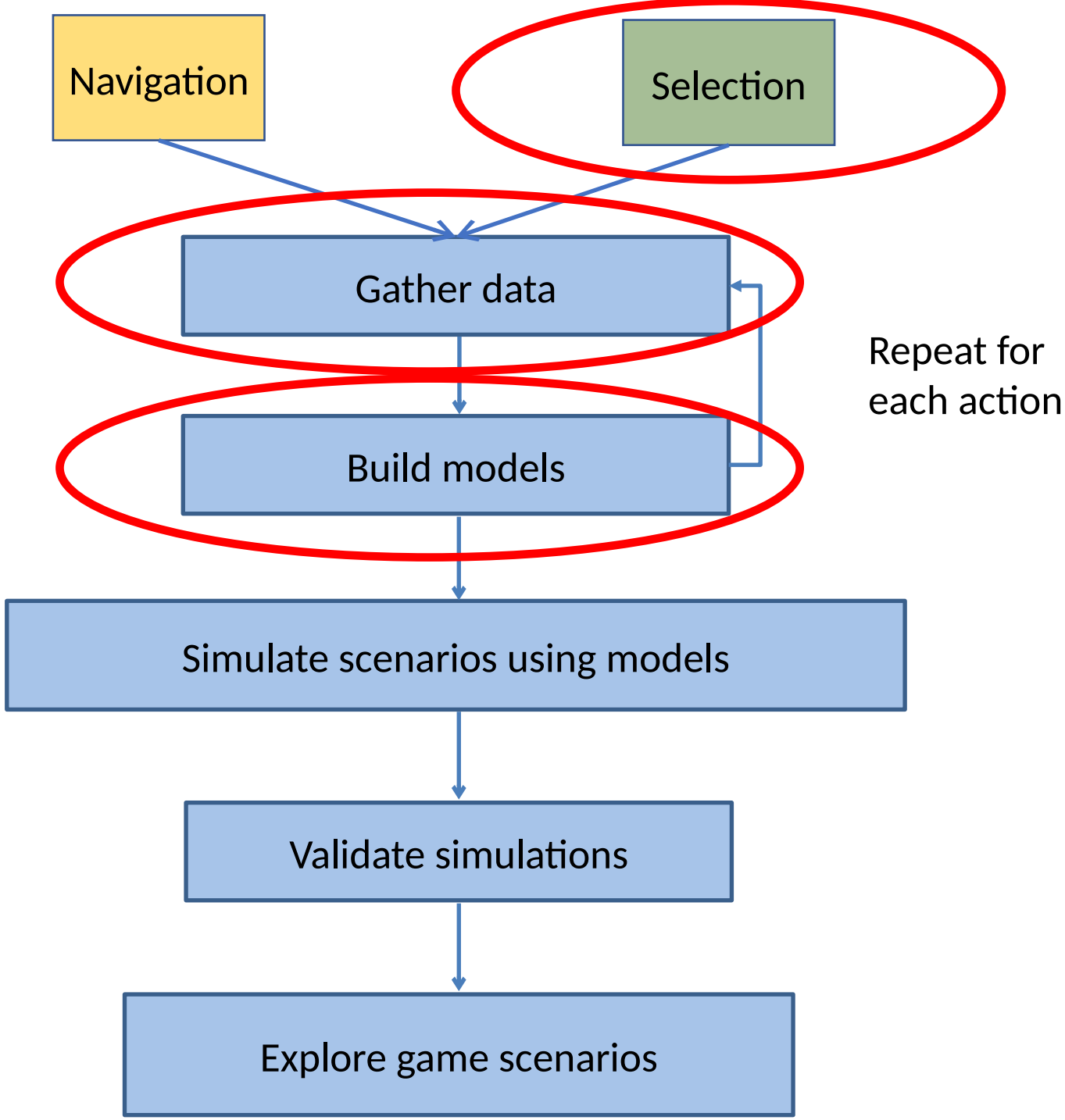
$R^2 = 0.99$



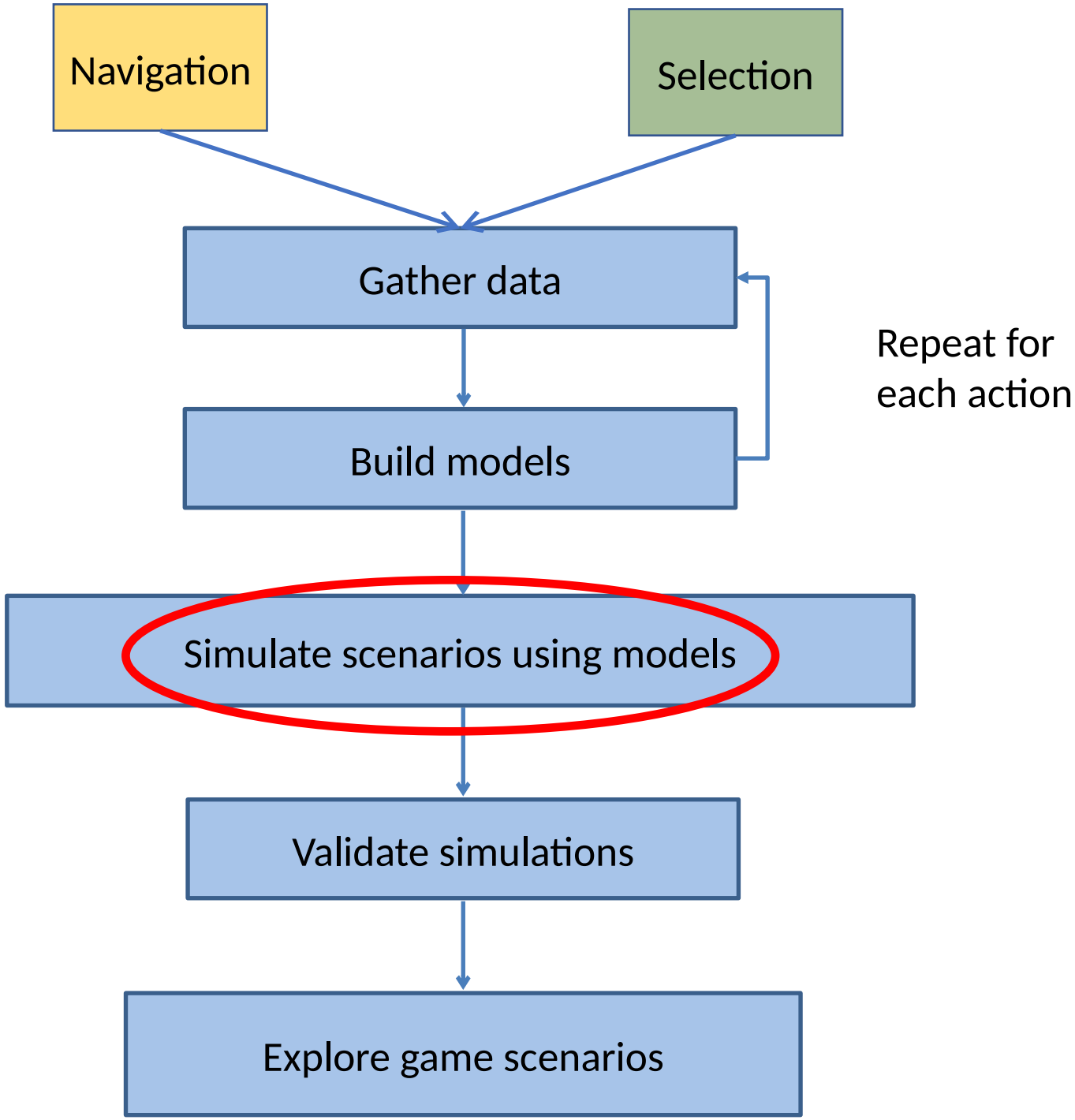
$$p = 1 - exp(-(\frac{out\_of\_sight\_window}{0.5})^{0.72})$$

$R^2 = 0.99$

Approach


Navigation
Selection
Gather data
Build models
Repeat for each action
Simulate scenarios using models
Validate simulations
Explore game scenarios

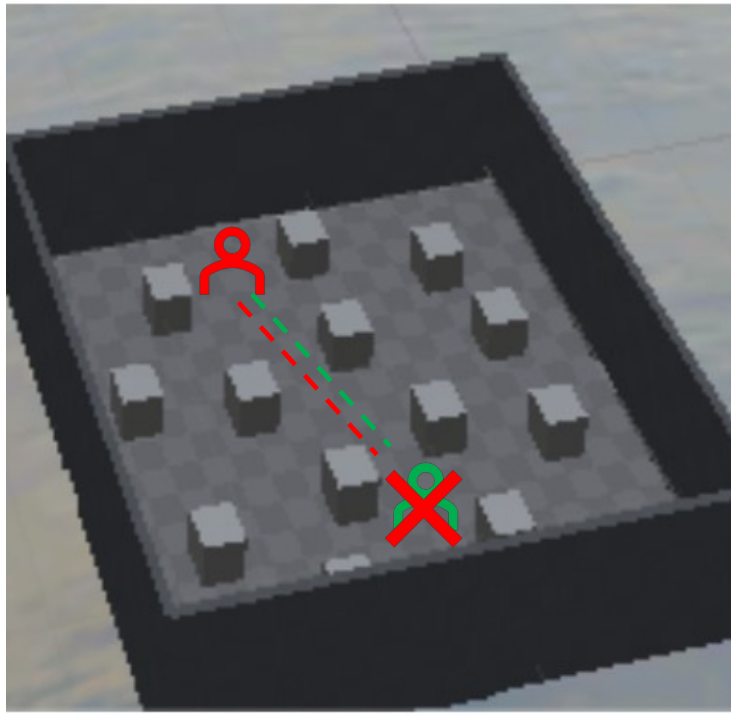
Approach


Navigation
Selection
Gather data
Build models
Repeat for each action
Simulate scenarios using models
Validate simulations
Explore game scenarios

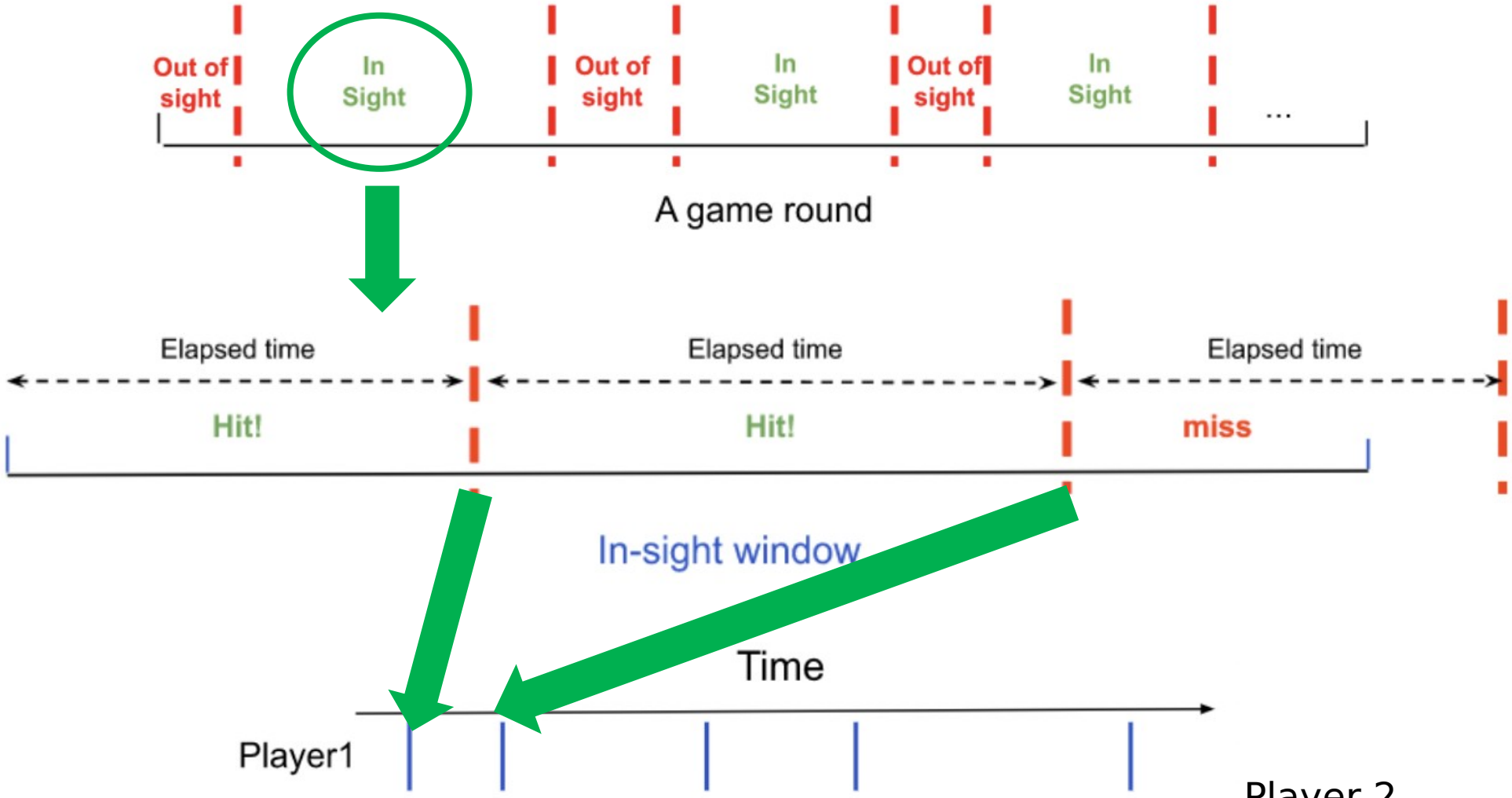
Simulation

Game:

- 2 player game
- Goal: Kill the opponent as fast as possible
- Whoever kills the opponent first wins the game

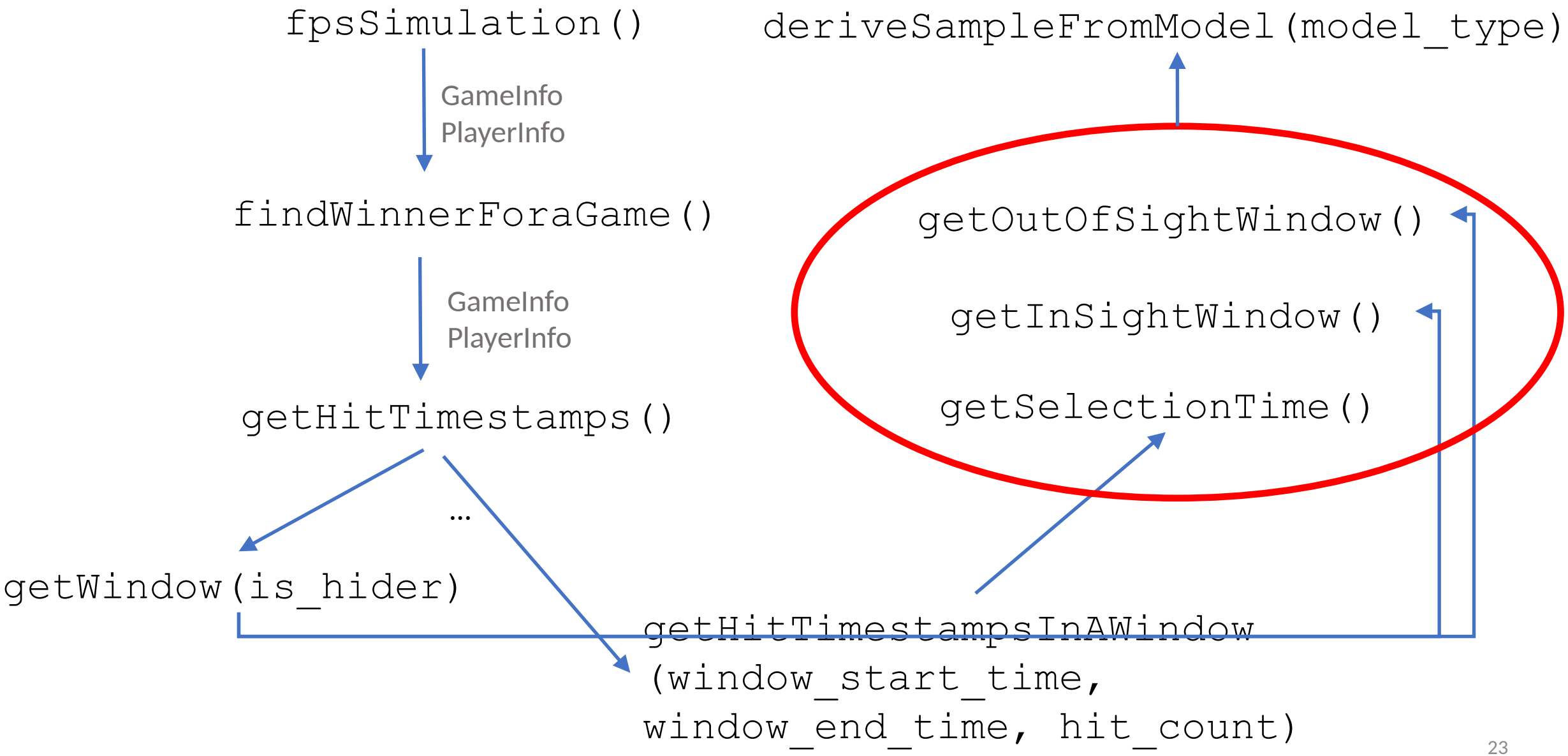


Simulation - overview



Player 2
5 hits first -- > winner!

Simulation pseudocode



Simulation pseudoc


```
function getHitTimestampsInAWindow (window_start_time,
    window_end_time, hit_count, gameInfo, playerInfo){

}
```

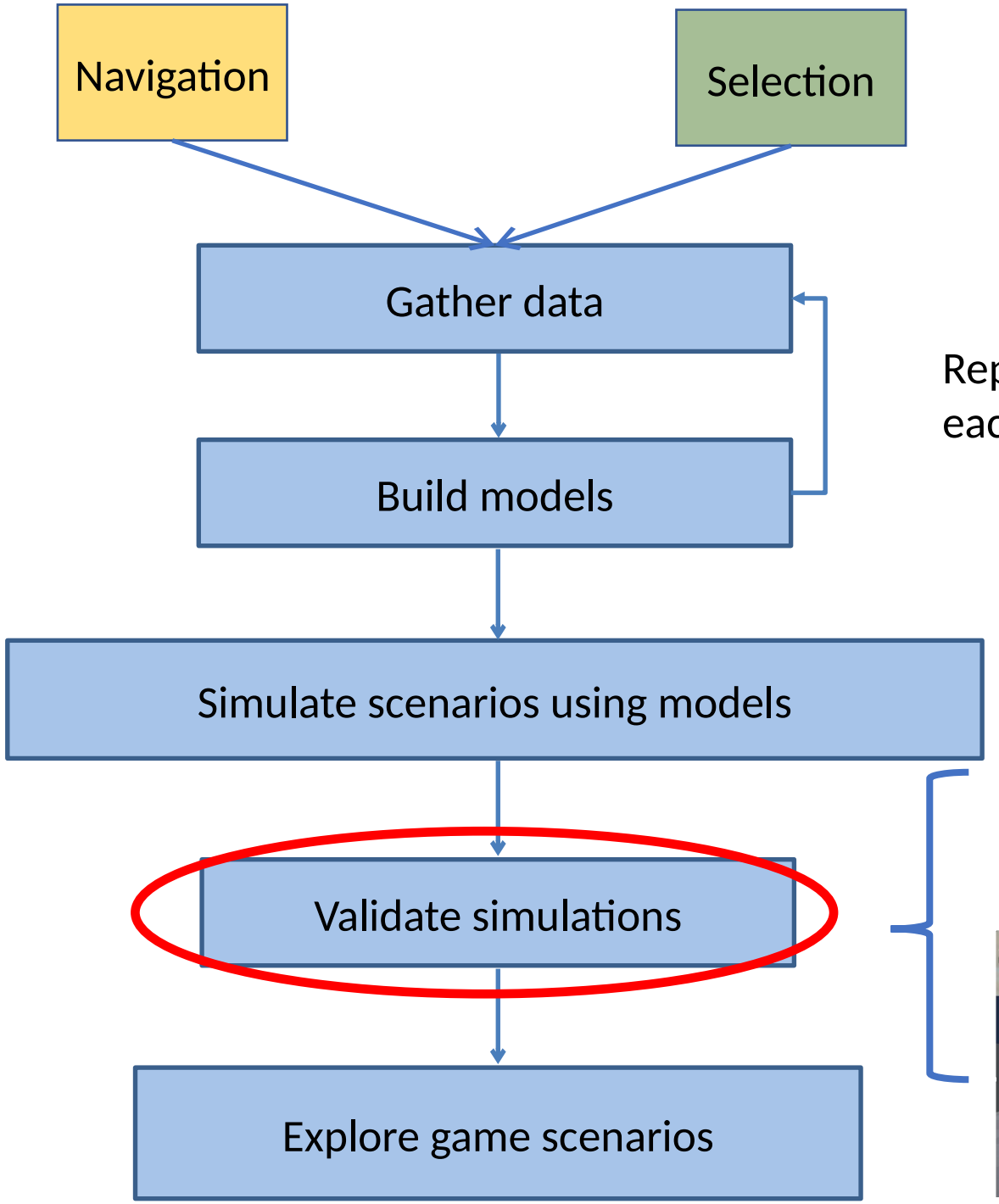
Simulation pseudoc


```
function getHitTimestampsInAWindow (window_start_time,
    window_end_time, hit_count, gameInfo, playerInfo){
  hit_timestamps_window = []
  total_time = window_start_time #Timeline




}
```

Model:

$$p = 1 - a * exp^{-(b \cdot L + c) * T}$$

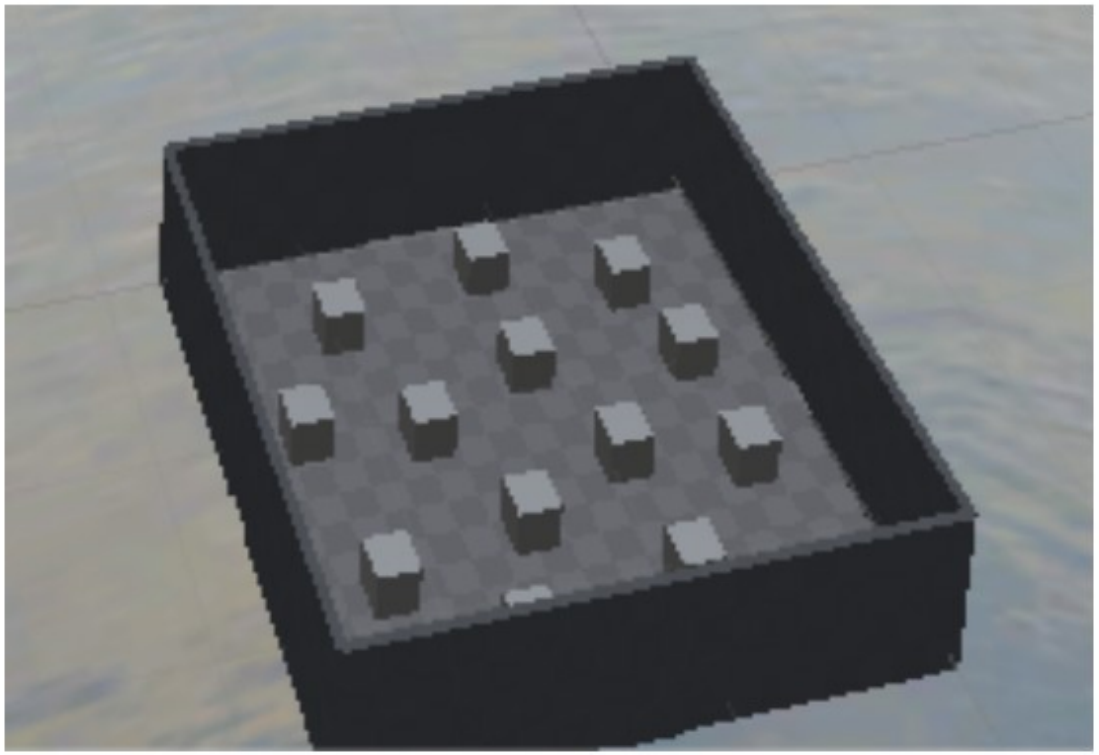
Approach


Navigation
Selection
Gather data
Build models
Repeat for each action
Simulate scenarios using models
Validate simulations
Explore game scenarios

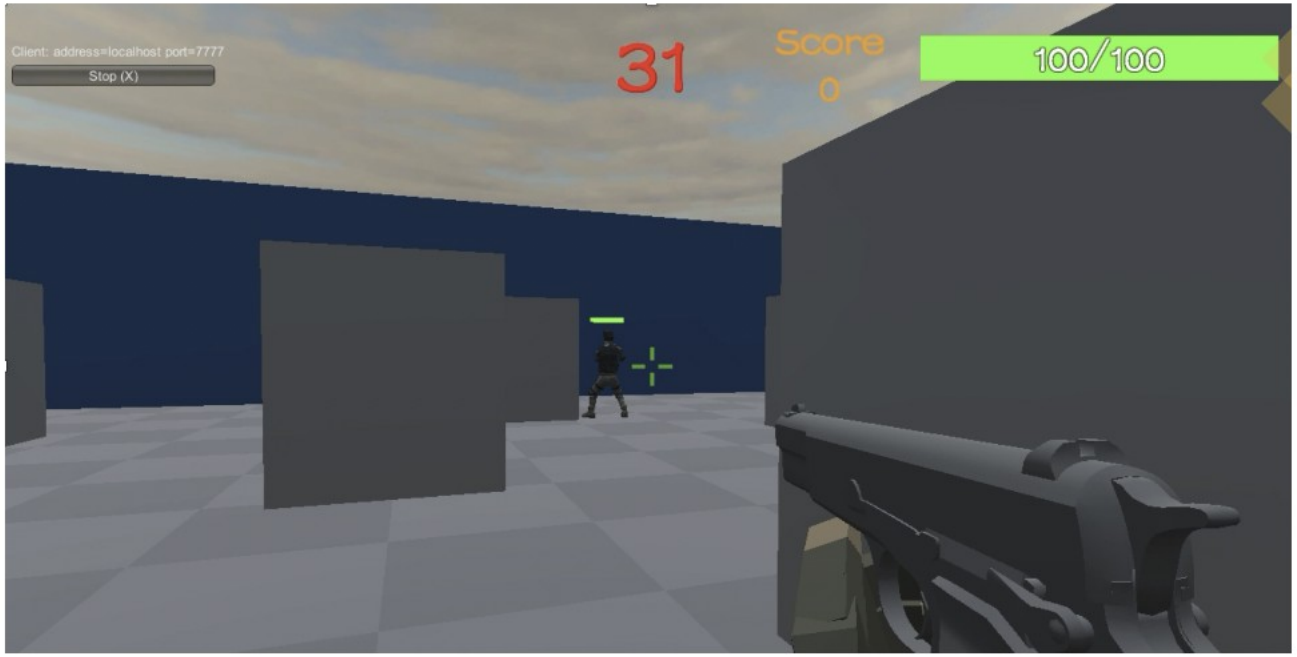

CS GO


31
Score
0
100 / 100

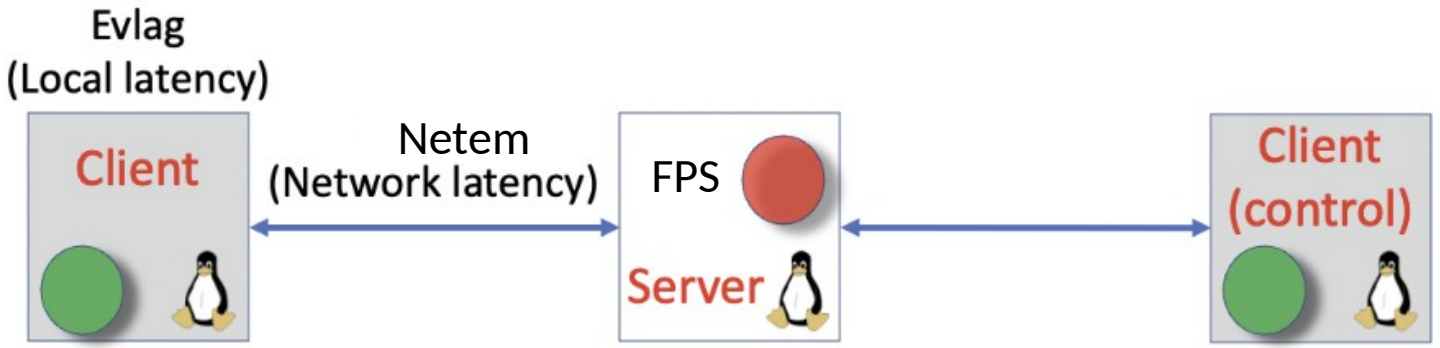
Validation user study



Map



Game screenshot



Validation user study

Parameters	Test player values	Control player values
Local latency	25, 100 (ms)	25 (ms)
Network latency	0, 150 (ms)	0 (ms)

Parameters	Values (same for both players)
Latency compensation	**none**, both time warp and self-prediction
Firing rate	**250**, 1000 (ms)
Number of hits required	**1**, 4
Target size	50, **200** (cm)
Movement speed	5, **10**
Map size	18 x 18 m, **36 x 36 m**

Conditions

A. Best condition (No latency, others default)
B. Vary local latency, network latency, latency compensation
C. Vary 5 game parameters under no latency and compensation
D. Vary 5 game parameters under 150 ms latency and no compensation
E. Vary 5 game parameters under 150 ms latency and compensation on

A * 3 + (B + C + D + E) * 2
= 39 rounds
+ 2 practice
~ 30 min total

Validation Demographics

T test: p = 0.69

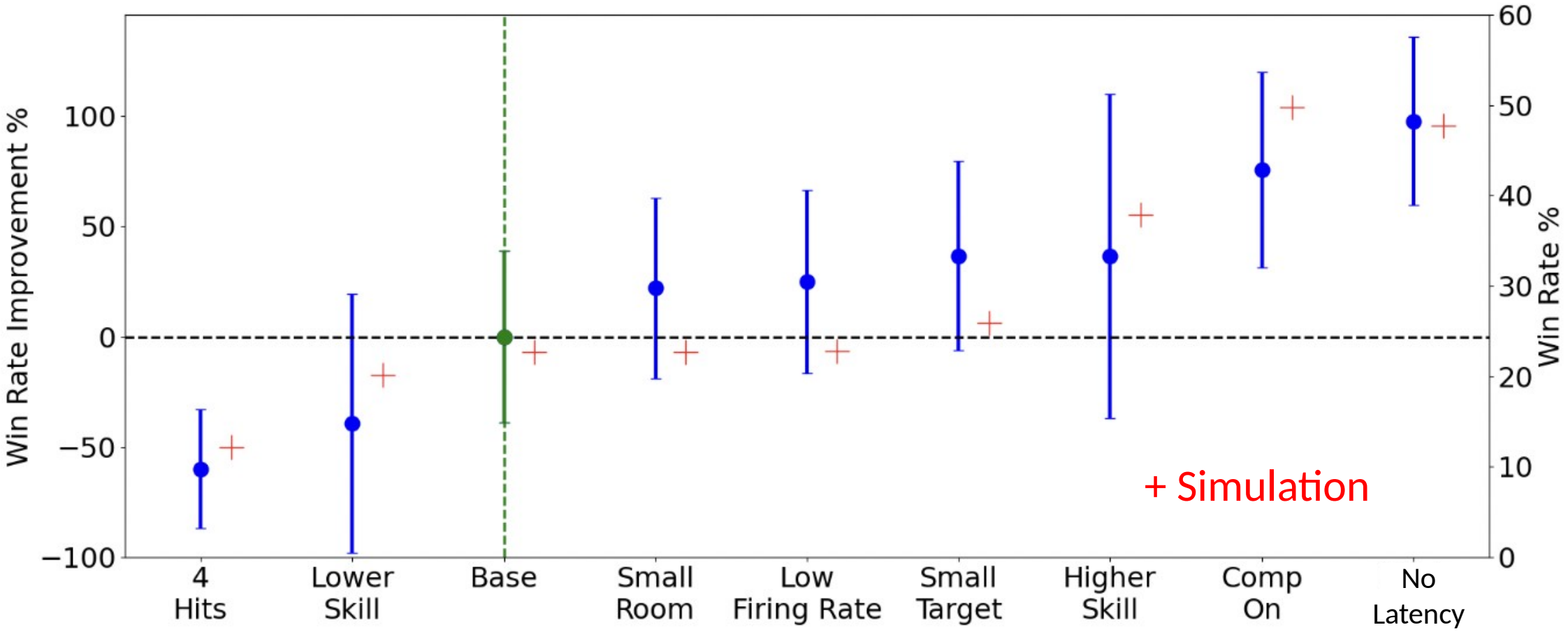
Test	Opponent
38	Control
8	Me

Group	Users	Age (yrs)	Gender	Gaming per week (hours)	Gamer Self-rating	FPS Self-rating	Reaction-time (ms)
Test	46	19.3 (3.0)	37♂ 6♀ 3 Other	13.6	3.4 (1.1)	2.8 (1.2)	183.3 (29.5)
Control	38	20.7 (3.9)	29♂ 8♀ 1 Other	12.8	3.5 (1.2)	3.1 (1.2)	196.1 (32.4)

Validation results

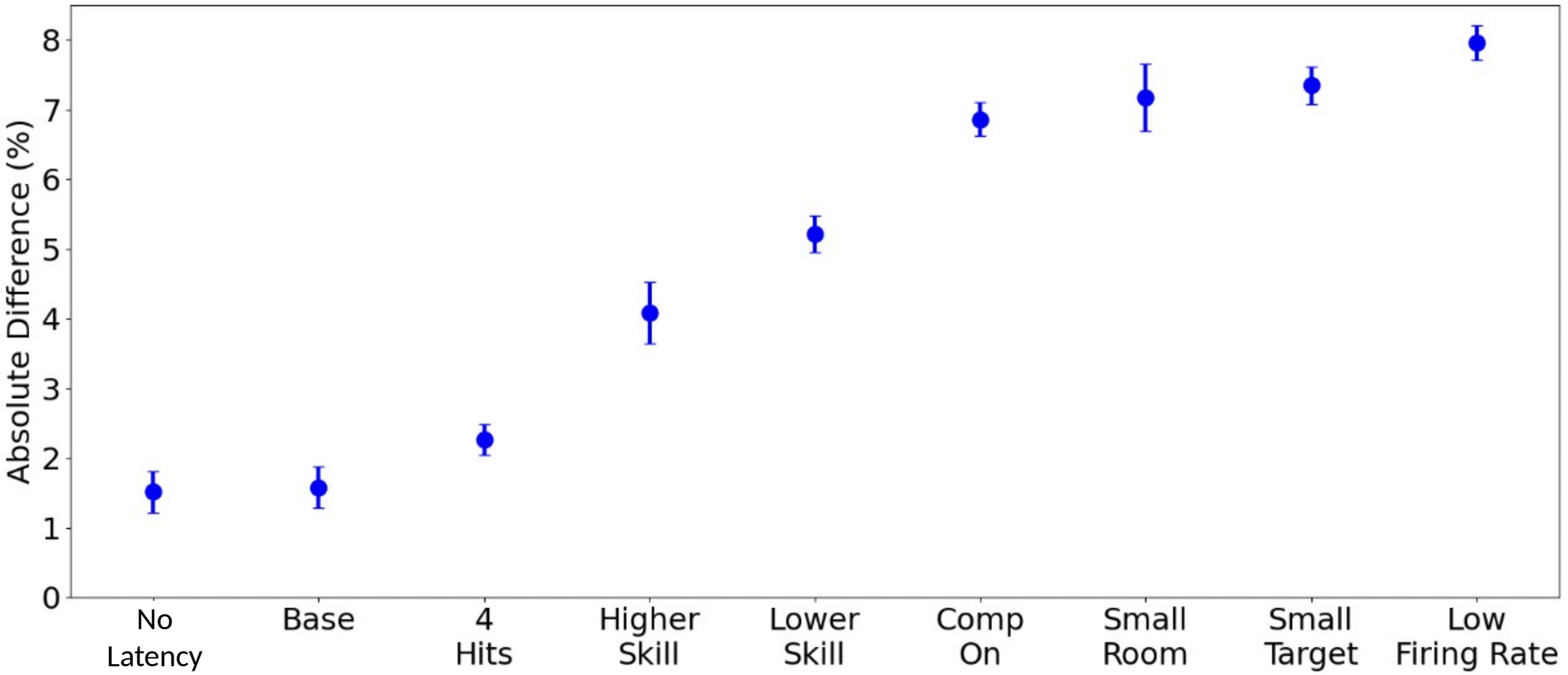
Parameter	Test player	Control player
Network latency	150 (ms)	0 (ms)
Local latency	25 (ms)	25 (ms)
Player skill	all	all
Latency compensation	none	
Firing rate	250 (ms) (4 shots per sec)	
Number of hits required	1	
Target size	200 cm	
Map size	36 x 36 m	

Validation results



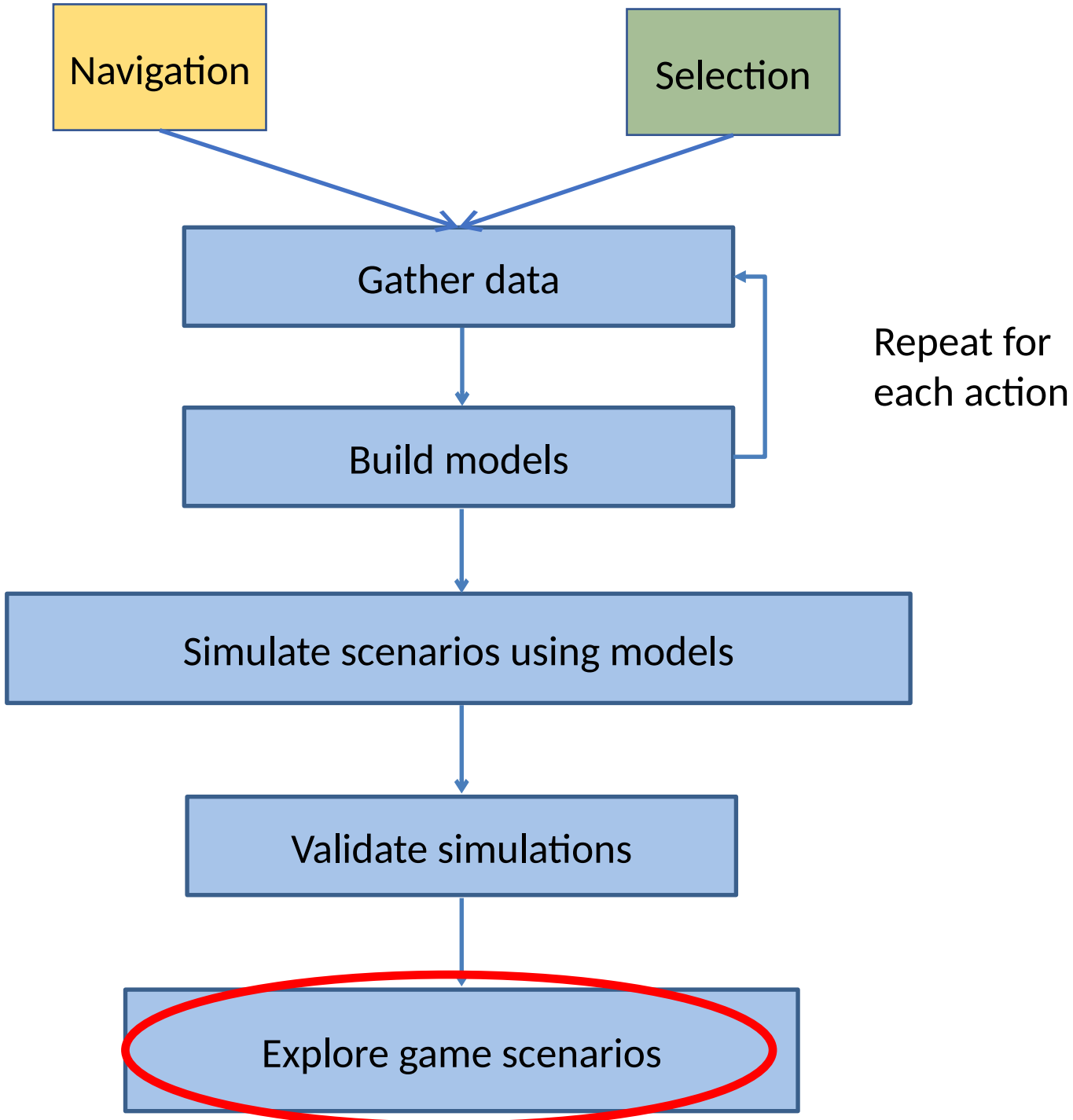
- Our simulation predicts scenarios in the custom FPS game well.

Validation Results



- Our simulation predicts scenarios in the custom FPS game well.

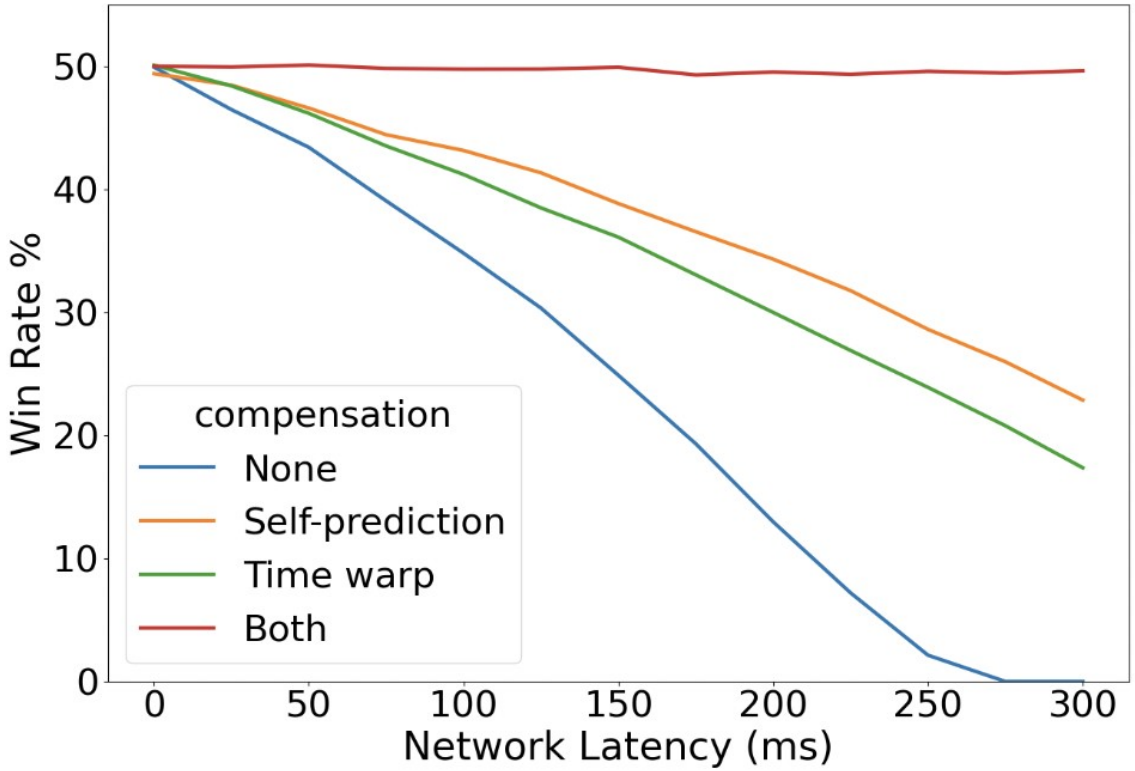
Approach


Navigation
Selection
Gather data
Build models
Repeat for each action
Simulate scenarios using models
Validate simulations
Explore game scenarios

Base Explorations

Parameters	Value
Local latency	25 (ms)
Player skill	all
Latency compensation	none
Firing rate	250 (ms) (4 shots per sec)
Number of hits required	1
Target size	200 cm
Map size	36 x 36 m
Network latency	0 - 300 ms

Exploration



- Both techniques together can nearly completely overcome the effects of network latency on player performance.

Exploration

Large Impact on latency

Medium impact on latency

Small impact on latency

Parameters	Default values	Win rate %
Network latency	150 ms	24.98
Local latency	25 (ms)	24.98
Latency compensation	none	24.98
Number of hits	1	24.98
Player skill	all	24.98
Firing rate (w/ 10 hits)	4 (shots/sec)	4.62
Map size	36 x 36 m	24.98
Target size	200 cm	24.98
Firing rate (w/ 1 hit)	4 (shots/sec)	24.98

Future work

Conclusions

Contributions

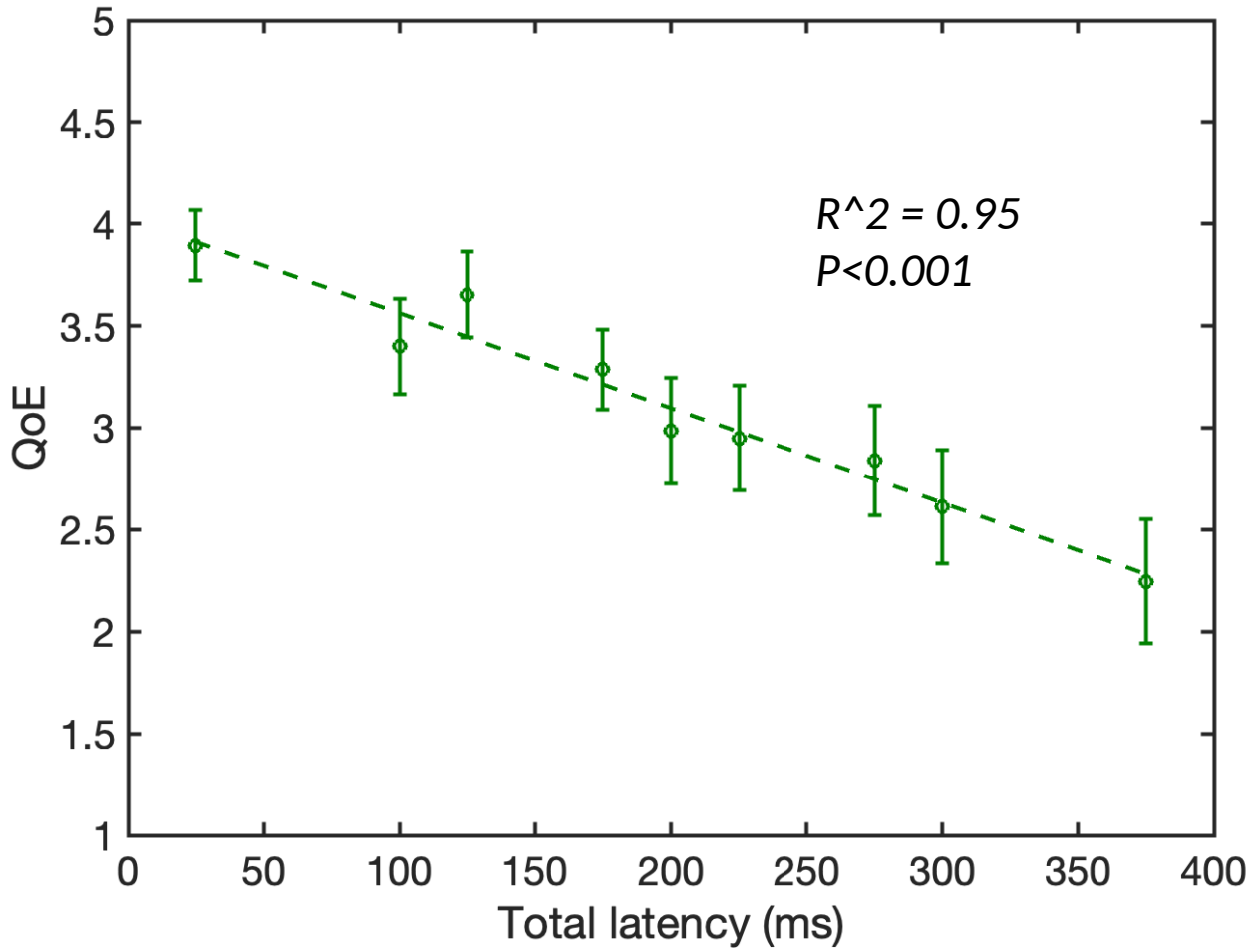
- Navigation
  - Impact of latency
  - Models of in-sight and out-of-sight time windows
- Selection
  - Impact of latency
  - A model of elapsed time
- Simulations
  - Validated
  - Parametrized by many FPS parameters
- Explorations

[*Call of Duty*, Activision, 2003]

THANKS FOR YOUR ATTENTION!

ANY QUESTIONS?

Results (QoE) Remove



An increase in total latency by 100 ms decreases player QoE by half a point on a 5-point scale

Related publications

Liu, Shengmei, Xiaokun Xu, and Mark Claypool. "A Survey and Taxonomy of Latency Compensation Techniques for Network Computer Games." ACM Computing Surveys (CSUR) (2022).

Liu, Shengmei, and Mark Claypool. "The Impact of Latency on Navigation in a First-Person Perspective Game." CHI Conference on Human Factors in Computing Systems. 2022.

Liu, Shengmei, et al. "Lower is better? The effects of local latencies on competitive first-person shooter game players." Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems. 2021.

Liu, Shengmei, et al. "The Effects of Network Latency on Competitive First-Person Shooter Game Players." 2021 13th International Conference on Quality of Multimedia Experience (QoMEX). IEEE, 2021.

Liu, Shengmei, and Mark Claypool. "EvLag: A Tool for Monitoring and Lagging Linux Input Devices." Proceedings of the 12th ACM Multimedia Systems Conference. 2021.

Related publications

Liu, Shengmei, et al. "L33t or N00b? How Player Skill Alters the Effects of Network Latency on First Person Shooter Game Players." Proceedings of the Workshop on Game Systems (GameSys' 21). 2021.

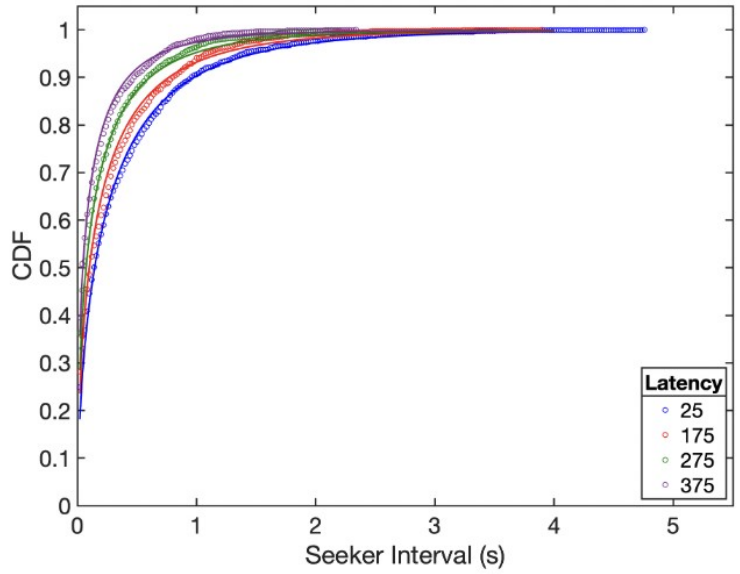
Liu, Shengmei, et al. "Datasets: Moving Target Selection with Delay." Proceedings of the 12th ACM Multimedia Systems Conference. 2021.

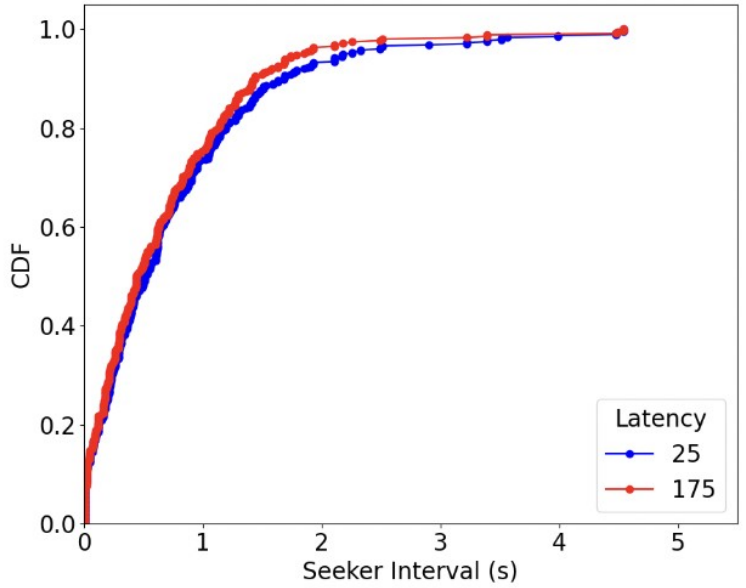
Liu, Shengmei, et al. "Comparing the Effects of Network Latency versus Local Latency on Competitive First Person Shooter Game Players." (2021).

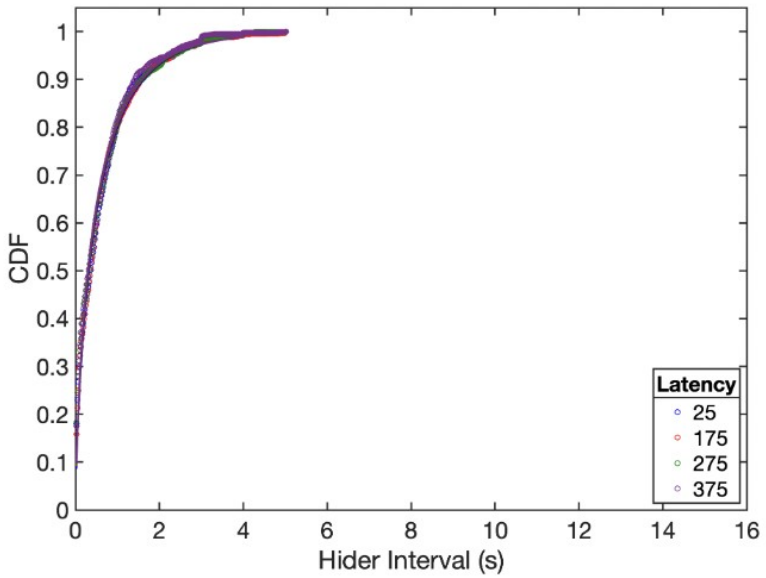
Liu, Shengmei, et al. "'Git Gud!'--Evaluation of Self-Rated Player Skill Compared to Actual Player Performance." Extended Abstracts of the 2020 Annual Symposium on Computer-Human Interaction in Play. 2020.

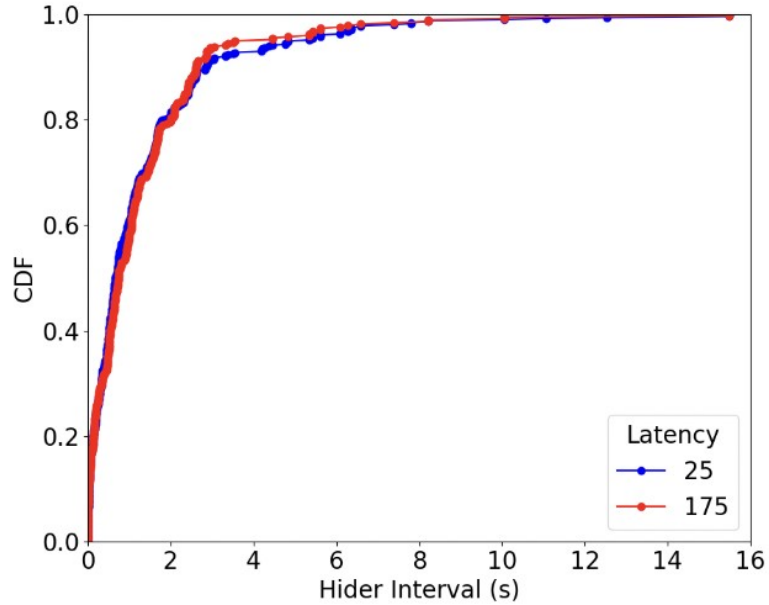
Liu, Shengmei, and Mark Claypool. "Game Input with Delay–A Model of the Time Distribution for Selecting a Moving Target with a Mouse." International Conference on Multimedia Modeling. Springer, Cham, 2021

Results Prune



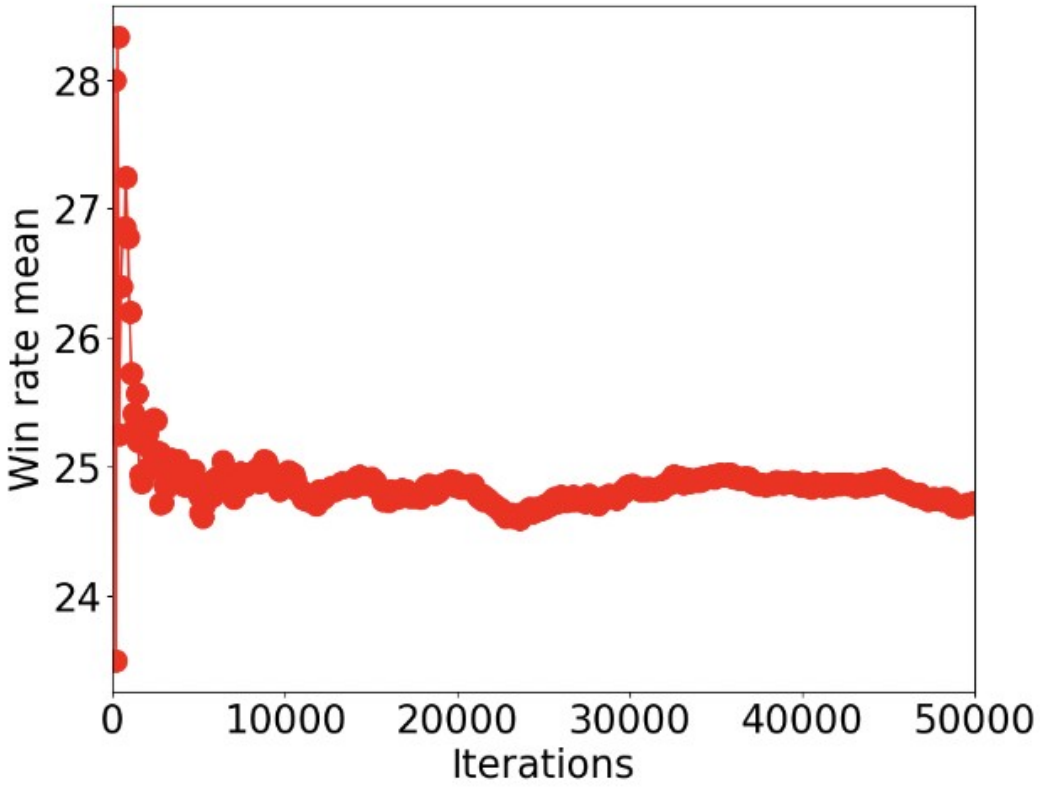


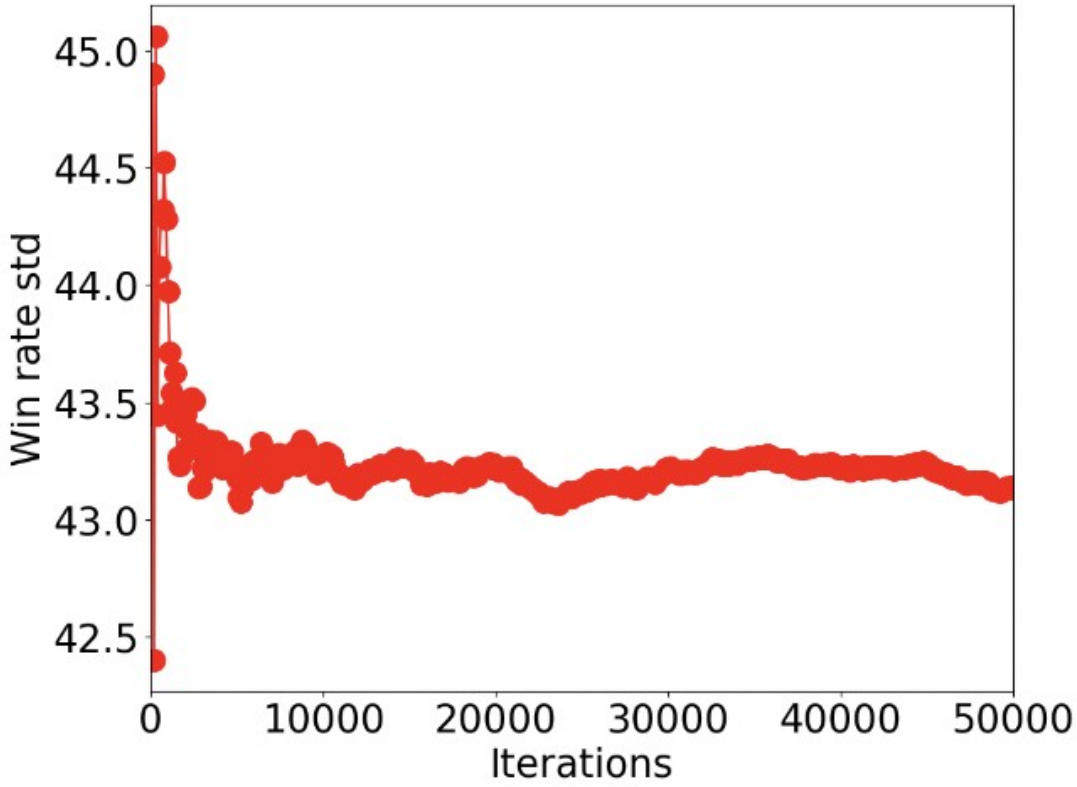




- CDF shapes are similar between two datasets
- Intervals in the FPS game study are longer in general

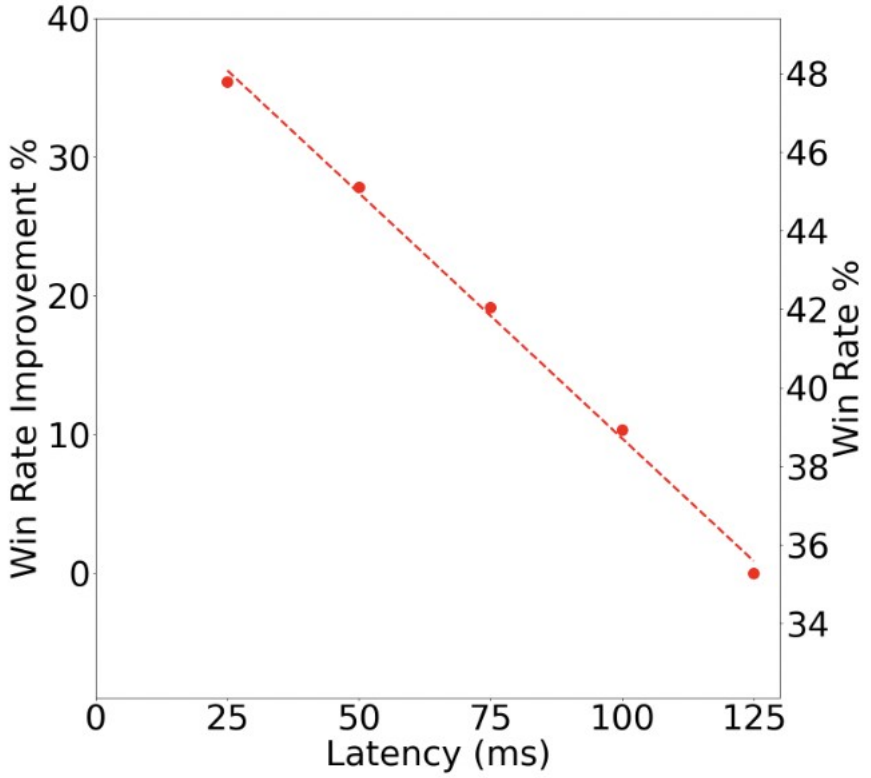
Simulation

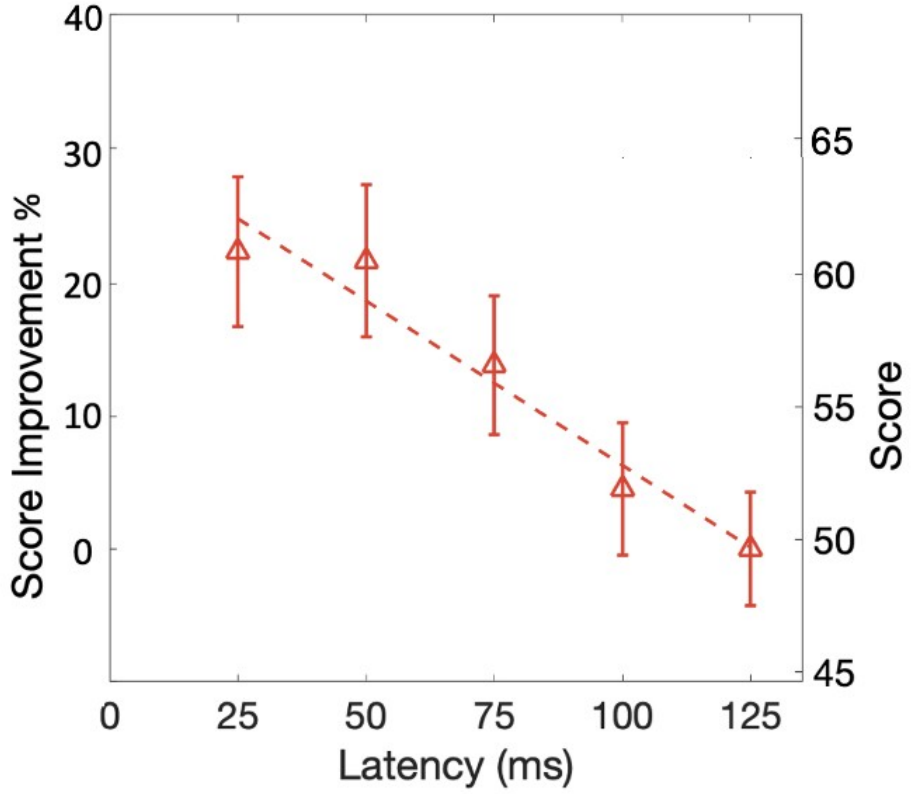




- Win rate mean and standard deviation are more stable with number of iterations over 10,000
- We use 100,000 as the number of iterations in following explorations

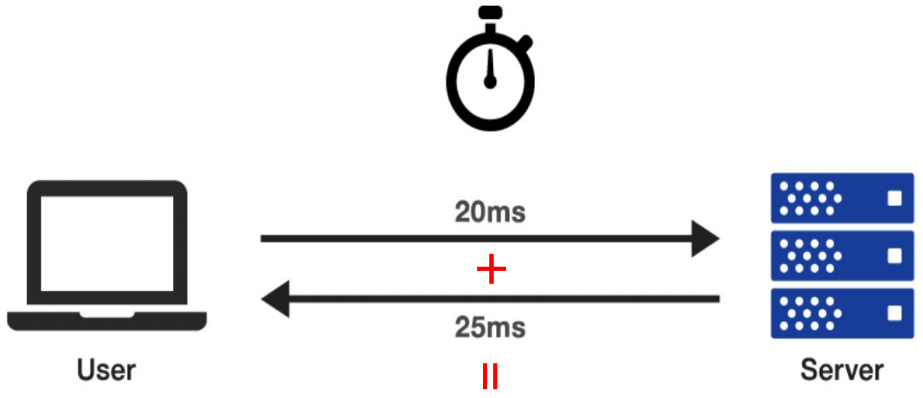
Validation with CS:GO





- Player performance degrades linearly in the range of 25 - 125 ms
- Player performance improves about 34% in our simulation and 25% in the CS:GO study

User study - navigation



II

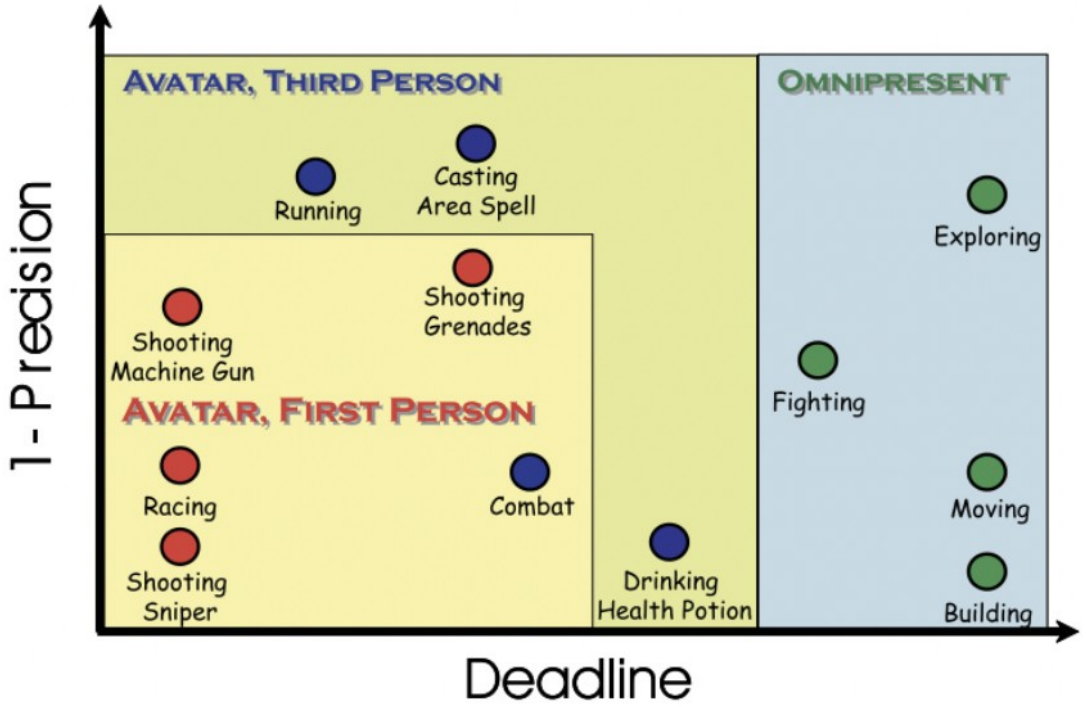
Network latency

Local latency

Performance

Latency and gamers

[*Call of Duty*, Activision, 2003]



[Claypool and Claypool, 2010]

[Liu et al., 2021]

Related work – Players

Reaction time:

[Ric14, Huma, Kos08, TG05, BS99, HPM91, Whe0]

- Gamers tend to have shorter reaction time

Player skill:

[Cla18, AJG+13, DWW05]

- Higher skill players are more resilient to latency

Related publications (In my thesis)

Chapter 5

Shengmei Liu and Mark Claypool. "The Impact of Latency on Navigation in a First-Person Perspective Game." In *Proceedings of the ACM Conference on Human Factors in Computing Systems (CHI)*, New Orleans, LA, USA, April 30 - May 5, 2022.

Chapter 6

Shengmei Liu and Claypool, Mark. “The Impact of Latency on Target Selection in First-Person Shooter Games”, *ACM Multimedia Systems Conference (MMsys)*, Vancouver, Canada, June 7 - 10, 2023. *(Under review)*

Chapter 8

Shengmei Liu, Atsuo Kuwahara, James Scovell, Jamie Sherman, and Mark Claypool. "Lower is Better? The Effects of Local Latencies on Competitive First-person Shooter Game Players." In *Proceedings of the ACM Conference on Human Factors in Computing Systems (CHI)*, Virtual Conference, May 8-13, 2021.

Chapter 8

Shengmei Liu, Atsuo Kuwahara, James Scovell, Jamie Sherman, and Mark Claypool. "The Effects of Network Latency on Competitive First-Person Shooter Game Players." In *Proceedings of the 13th International Conference on Quality of Multimedia Experience (QoMEX)*, Virtual Conference, June 14-17, 2021.

Related publications (Inform my thesis)

Latency

Shengmei Liu, Atsuo Kuwahara, James Scovell, Jamie Sherman, and Mark Claypool. "Comparing the Effects of Network Latency versus Local Latency on Competitive First Person Shooter Game Players." In *Proceedings of the ACM Esports and High Performance HCI Workshop (EHPHCI)*, Virtual Conference, May 8, 2021.

Latency

Xiaokun Xu, Shengmei Liu, and Mark Claypool. "The Effects of Network Latency on Counter-strike: Global Offensive Players", In *Proceedings of the 14th International Conference on Quality of Multimedia Experience (QoMEX)*, Lippstadt, Germany, September 5-7, 2022.

Latency compensation

Shengmei Liu, Xiaokun Xu and Mark Claypool. “A Survey and Taxonomy of Latency Compensation Techniques for Network Computer Games.” ACM Computing Surveys (CSUR), January 2022

Related publications (Inform my thesis)

Player skill

Shengmei Liu, Atsuo Kuwahara, James Scovell, Jamie Sherman, and Mark Claypool."L33t or N00b? How Player Skill Alters the Effects of Network Latency on First Person Shooter Game Players." 2021 Proceedings of the Workshop on Game Systems (GameSys' 21).

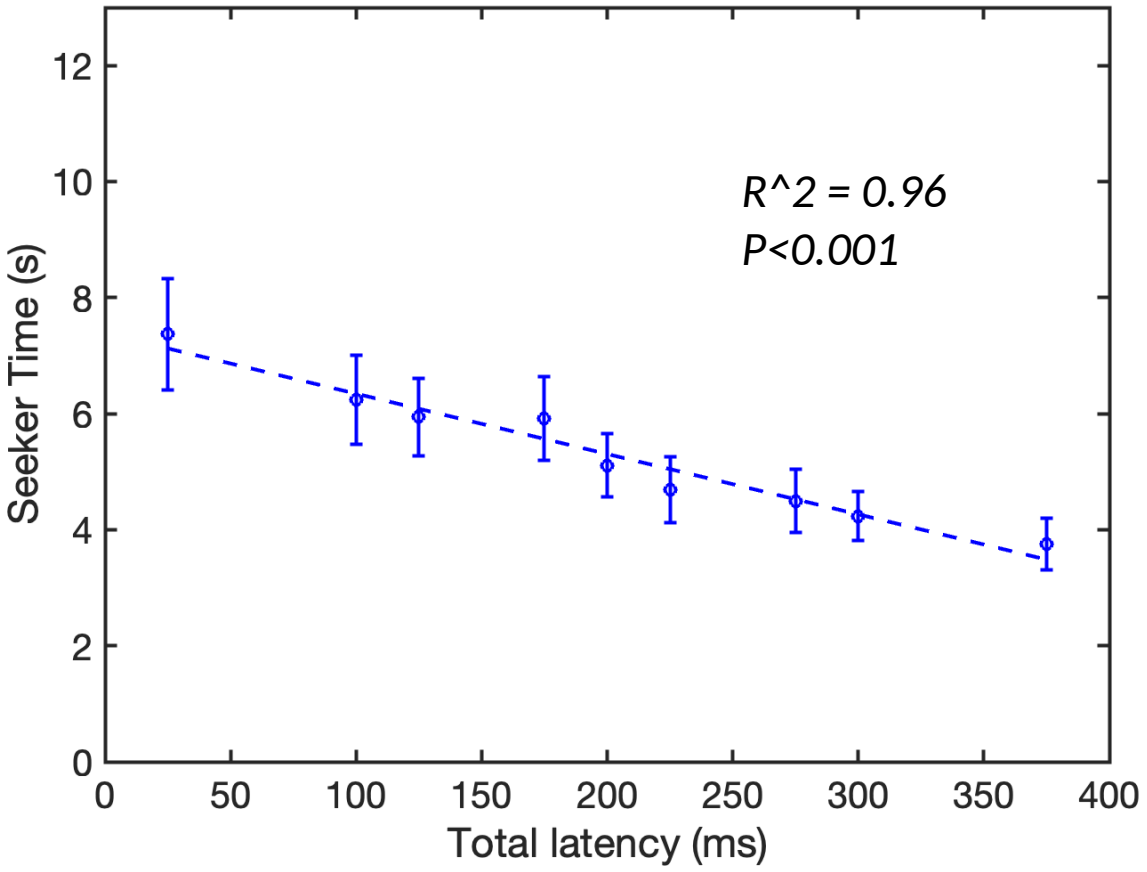
Player skill

Shengmei Liu, Mark Claypool, Bhuvana Devigere, Atsuo Kuwahara, and Jamie Sherman. "'Git Gud!'--Evaluation of Self-Rated Player Skill Compared to Actual Player Performance." In *Proceedings of the ACM Annual Symposium on Computer-Human Interaction in Play (CHI PLAY)*, (Work In Progress), Virtual Conference, November 2-4, 2020.

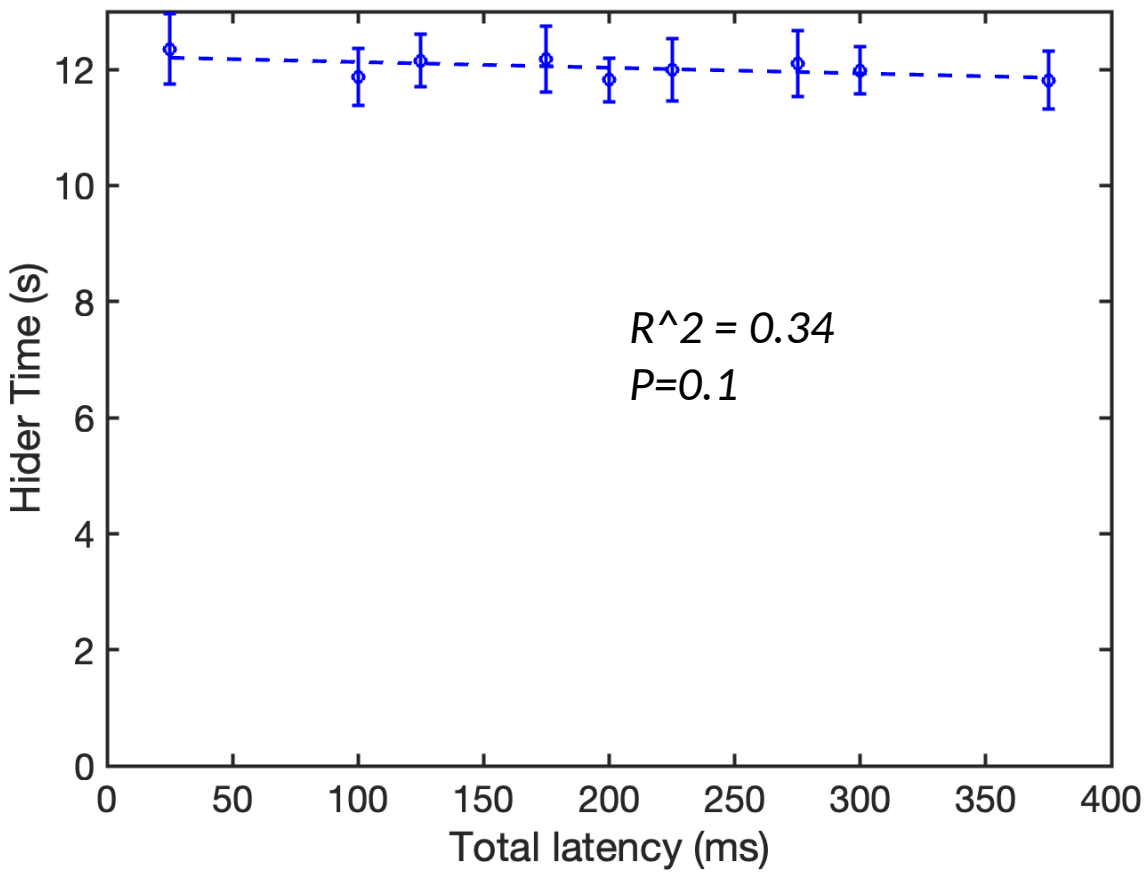
Methodology

Shengmei Liu and Mark Claypool. “Game Input with Delay – A Model of the Time Distribution for Selecting a Moving Target with a Mouse.” In *Proceedings of the 27th International Conference on MultiMedia Modeling (MMM)*, Virtual Conference, June 22-24, 2021.

Results (Seeker and Hider time) - navigation



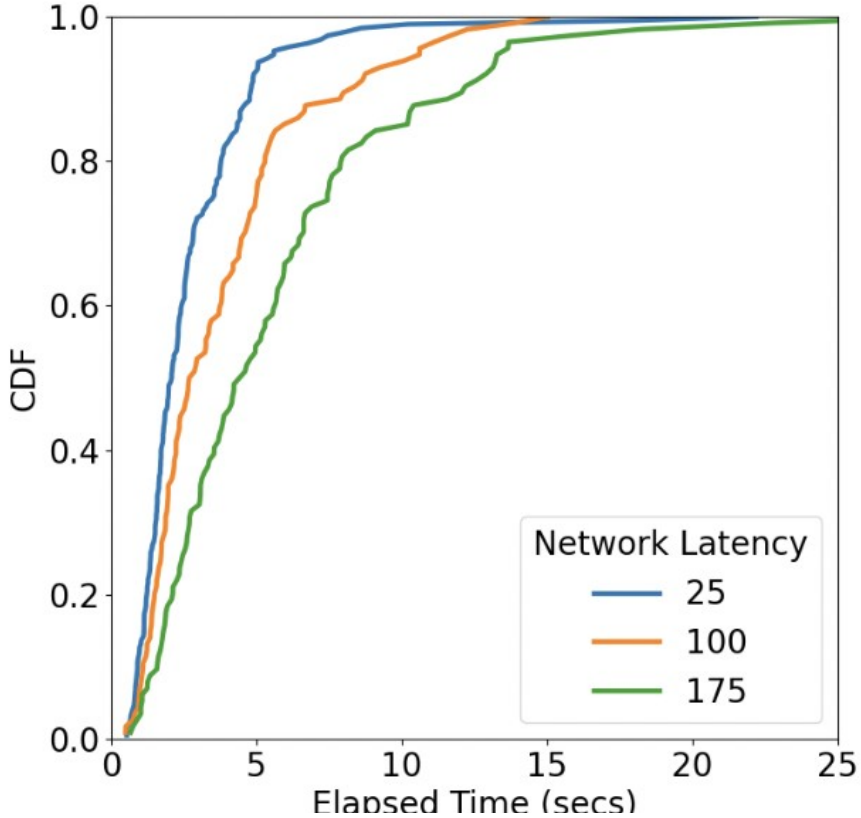
An increase in total latency by 100 ms degrades seeker time by 1.5 seconds per minute.



The ability of a player to hide from an opponent is not significantly impacted by latency

Models

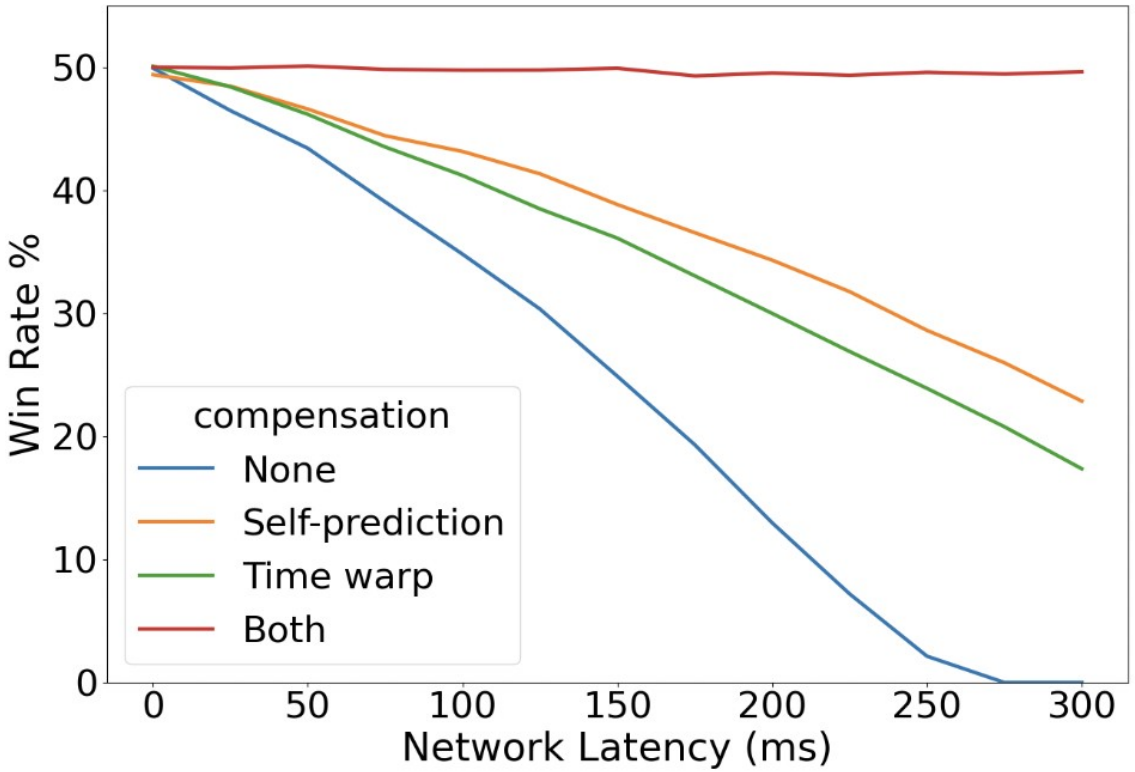
- *Selection*

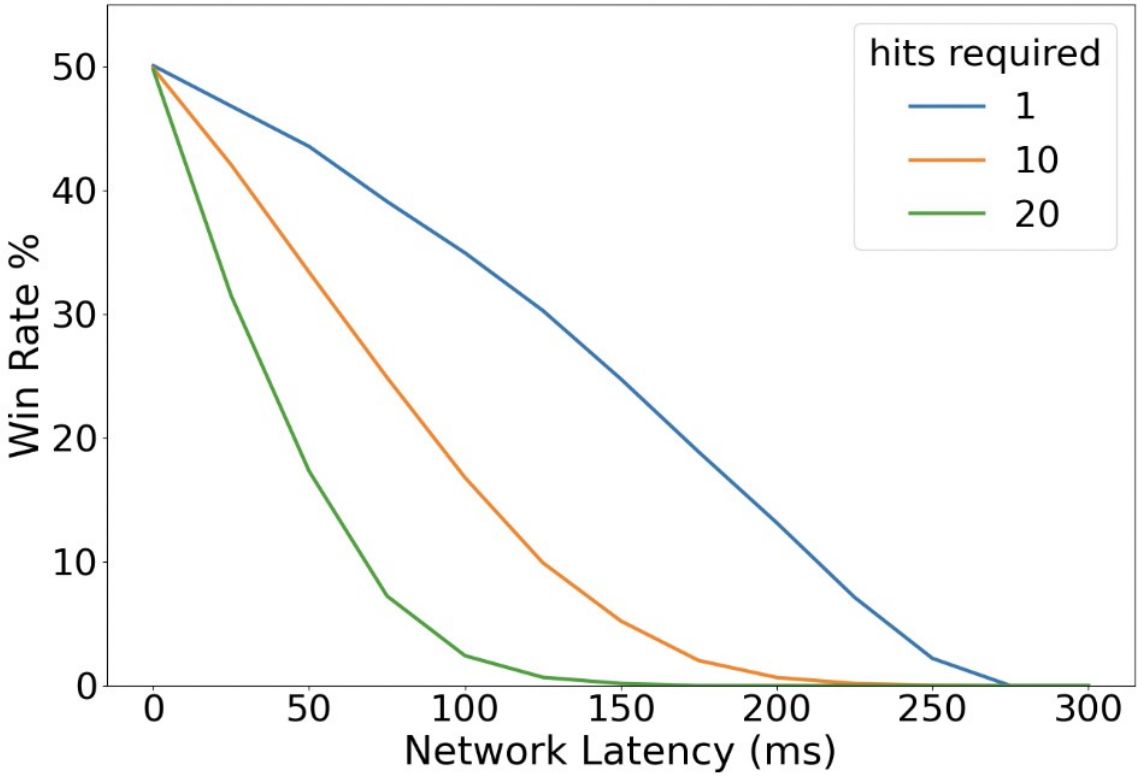


$$p = 1 - a \times exp(-(b \times (loc\_lat + net\_lat) + c \times firing\_rate + d \times 3D\_distance + e \times \frac{target\_size}{3D\_distance^2} + f) \times elapsed\_time)$$

$R^2 = 0.98$

Exploration



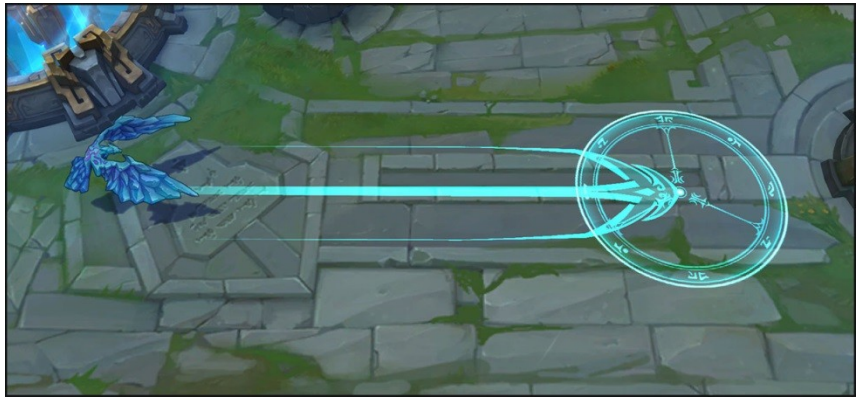


- Both techniques together can nearly completely overcome the effects of network latency on player performance.

- Player performance is more impacted by latency the greater the number of hits required for a kill.

Gaming actions - Selection

[Duck Hunt, Nintendo, 1984]



[League of Legends, Riot Games, 2009]

[*Call of Duty*, Activision, 2003]

...

Gaming actions - First-person navigation

Position A → Position B

Related work – Latency

Network latency:

[PW02, Arm03, QML+04, DWW05, FRS05, CC06, AJG+13, HCW+14, HFPG16]

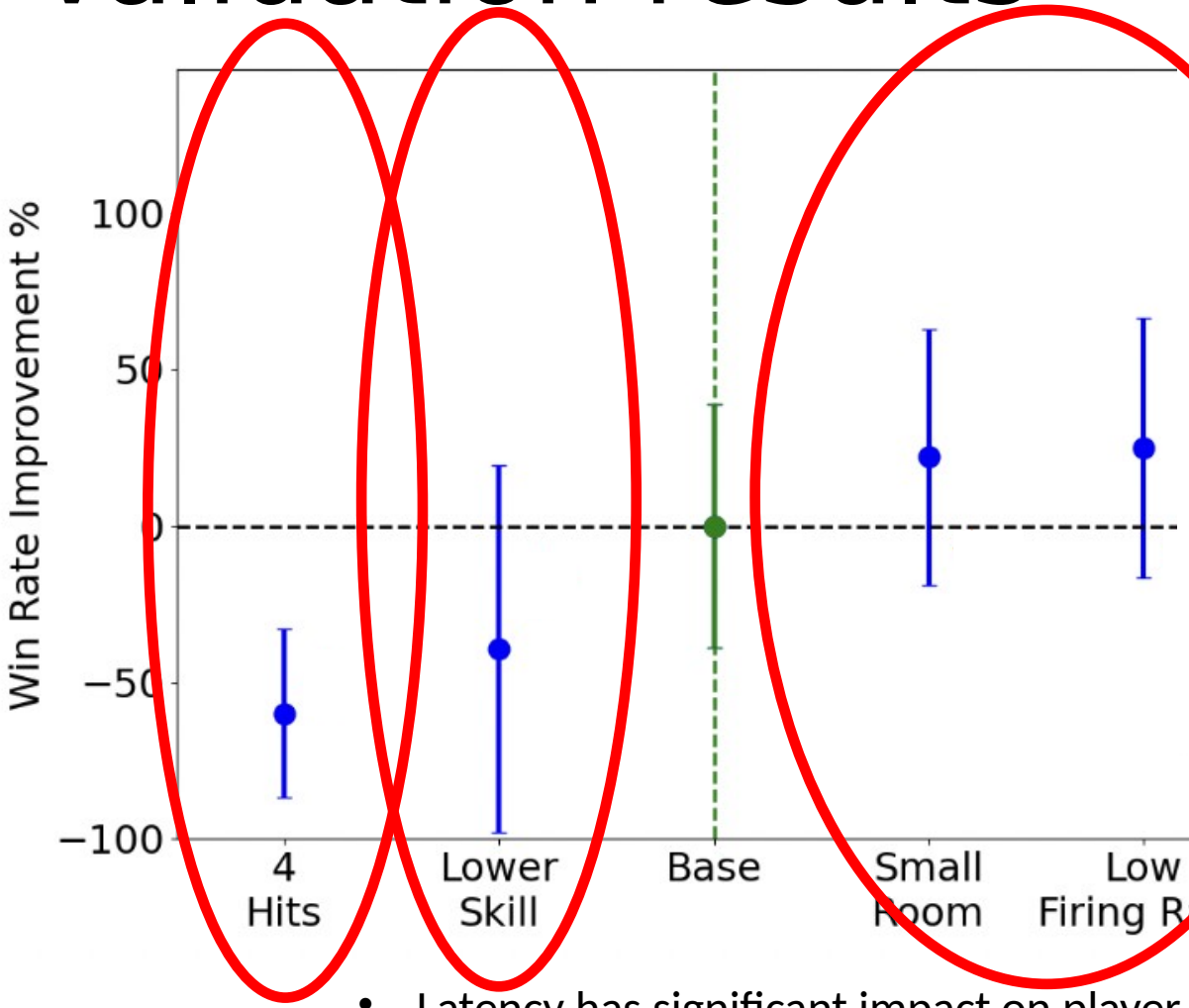
- Studies on specific game or game tasks
- Significant impact on players

Local latency:

[CC07, ISGS15, CER17, ERC18, LG18, LG19, LKS+21b].

- Studies on specific game or game tasks
- Significant impact on players

Validation results



Parameter	Test player	Control player
Network latency	150 (ms)	0 (ms)
Local latency	25 (ms)	25 (ms)
Player skill	all	all
Latency compensation	none	
Firing rate	250 (ms) (4 shots per sec)	
Number of hits required	1	
Target size	200 cm	
Map size	36 x 36 m	

- Latency has significant impact on player performance
- Latency compensation can significantly mitigate the effects of latency on player.
- More hits make it harder for players with network latency to win
- Room size and firing rate do not have significant impact on player win rates.

Latency and gamers

[*Call of Duty*, Activision, 2003]

[Liu et al., 2021]

Base Explorations

Parameter	Test player	Control player
Network latency	0 - 150 (ms)	0 (ms)
Local latency	25 (ms)	25 (ms)
Player skill	all	all
Latency compensation	none	
Firing rate	250 (ms) (4 shots per sec)	
Number of hits required	1	
Target size	200 cm	
Map size	36 x 36 m	