WPI

Uniquitous: Implementation and Evaluation of a Cloud-based Game System in Unity3d

IMGD M.S. Thesis Presentation

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Background (1/2)

- What is Cloud Gaming?
  - New service based on cloud computing technology
- Why Cloud Games?
  - Convenience for players
  - Efficiency for developers
  - Reduce piracy for publishers

Background (2/2)

- Existing Cloud Gaming Systems
  - OnLive, Gaikai, StreamMyGame, GamingAnywhere etc.

- Cloud Games Are Growing Fast
  - Estimated to grow from $1 billion in 2010 to $9 billion in 2017 [1]
  - In 2012, Sony bought Gaikai service for $380 million and integrated the service into PlayStation in Jan. 2014 [2]

Motivation (1/2)

- Major Challenges for Cloud Gaming Providers
  - Network latency
  - Higher bandwidth required, e.g. 2 Mbps min for OnLive [3]
  - System processing delay
- Need Effective Cloud Gaming Testbed for Research and Development
  - Commercial cloud gaming systems (e.g. OnLive)
    - Proprietary
  - Academic cloud gaming systems (e.g. GamingAnywhere)
    - No access to and not integrated with the source code of games

Motivation (2/2)

- Uniquitous
  - More flexible and easily accessed cloud gaming system implemented with Unity3d
  - Convenient for Unity developers (1 million, 2012 to 2.5 million, 2014, 0.6 million monthly [4])
  - Allows modifications to internal structures, configurations on system parameters
  - Allows game content adjustments
    - Different game scene complexities
    - Different camera views

- Evaluation of Uniquitous
  - Micro evaluation
  - Macro evaluation

Outline

- Introduction
- Related Work
- Implementation
- Micro Evaluation
- Macro Evaluation
- Conclusion and Future Work

Related Work (1/2)

- Cloud Systems
  - Cloud system architecture
    - Foster et al. [5] defined a four-layer model for cloud system architecture (fabric layer, Unified resource layer, Platform layer and Application layer)
  - Cloud services
    - Foster et al. [5] listed the services at three different levels: Infrastructure as a Service (IaaS), Platform as a Service (PaaS), Software as a Service (SaaS)
- Cloud Gaming Frameworks
  - Three approaches classified by Huang et al. [6]
    - Video streaming approach
    - 3D graphics streaming approach
    - Video streaming with post-rendering operations approach

Related Work (2/2)

- System Measurement
  - Measuring system delays
    - Huang et al. [6] -- Measuring the delay of each system subcomponent of GamingAnywhere
  - Three system parameters affecting players' experience: frame rate, game quality and game resolution
    - Chang et al. [7] -- Frame rate and game quality degradation are both critical to gaming performance. Frame rate has a greater impact
    - Claypool et al. [8] -- Frame rate has a greater influence on gaming performance than game resolution

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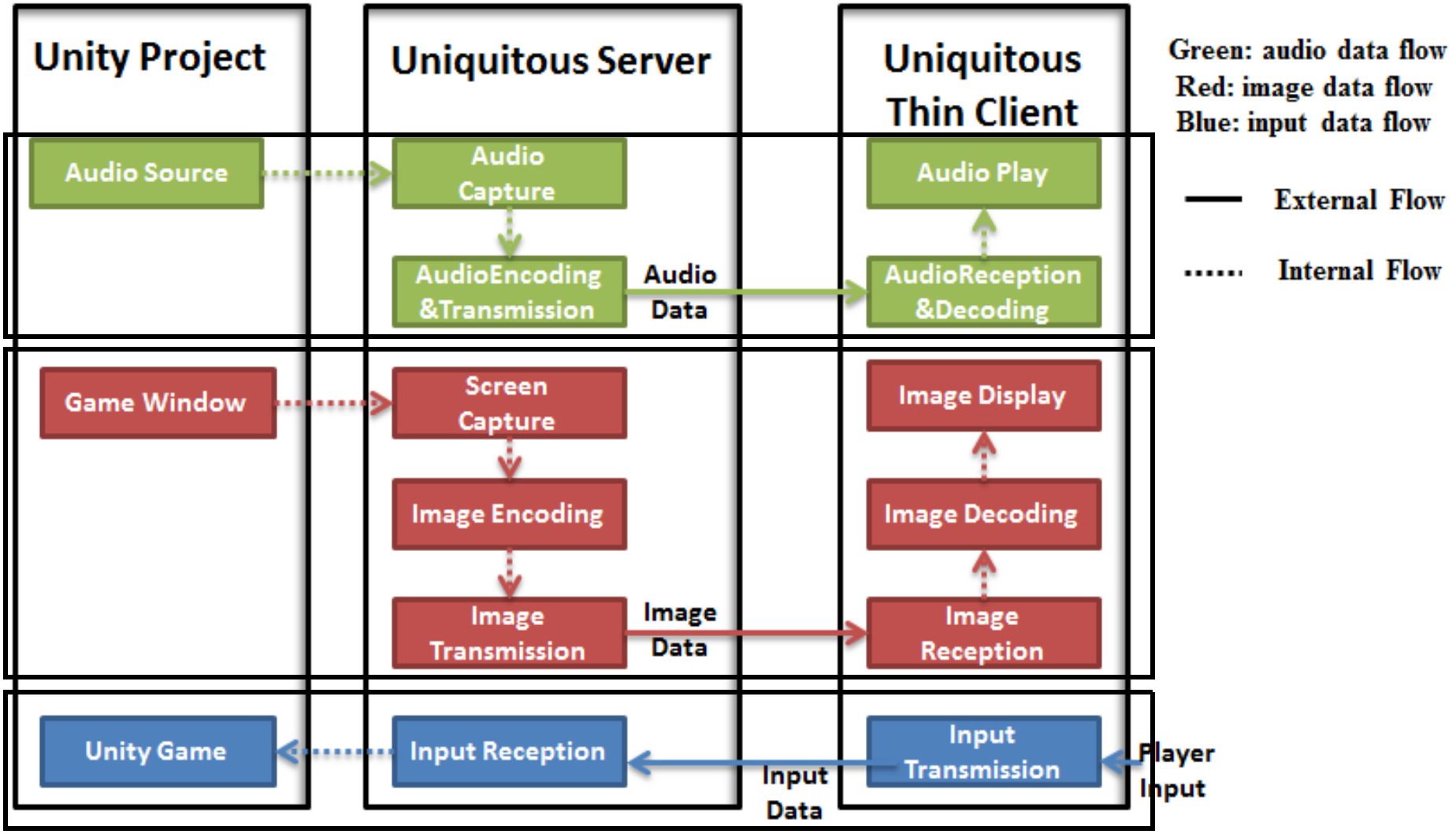
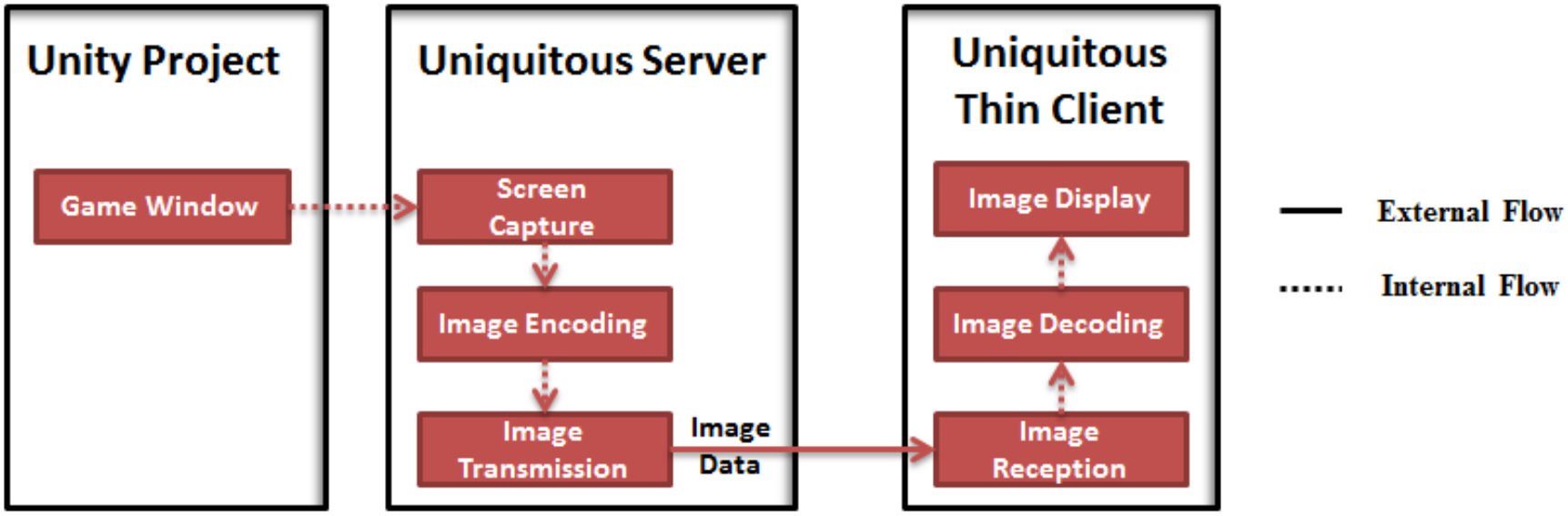
Implementation (1/4)



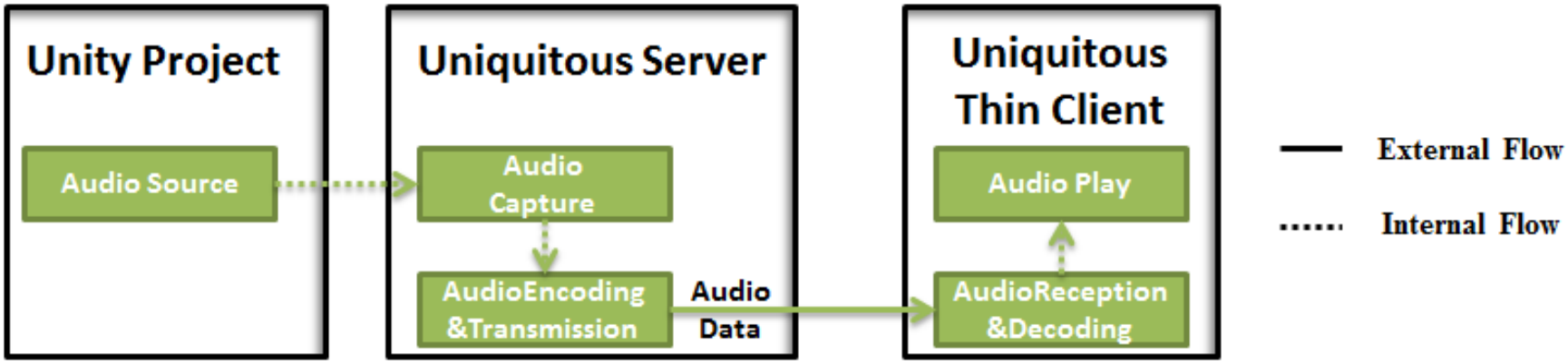
Implementation (2/4)

- Image Data Flow: carry data for the game frames
  - Image Encoding : JPEG encoder
  - Image Transmission : unreliable remote procedural call (RPC)



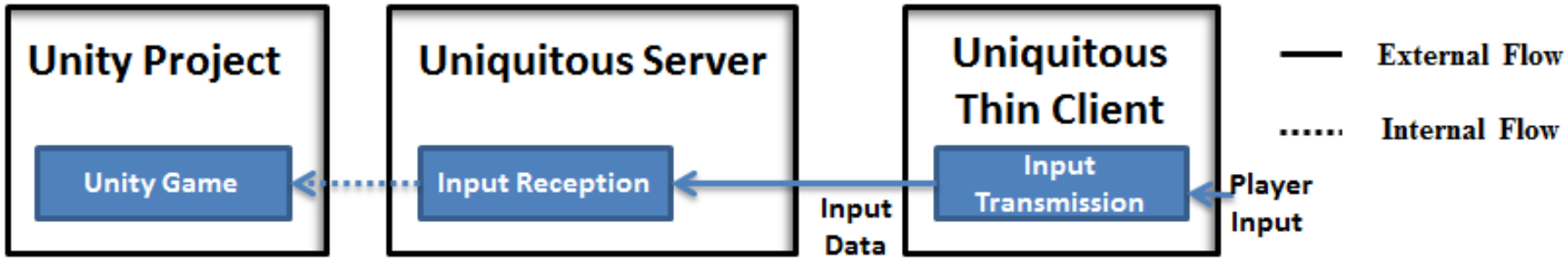
Implementation (3/4)

- Audio data flow: carry data for the game audio
  - Audio Source : Audio listener
  - Audio Capture : *OnAudioFilterRead*, TCP socket
  - Audio Encoding & Transmission : FFMPEG
  - Audio Reception & Decoding : FFPLAY



Implementation (4/4)

- Input data flow: carry data for user input
  - Input Transmission : unreliable remote procedural call (RPC)
  - Unity Game : game scripts affected by user input



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Micro Evaluation (1/6)

- Goal
  - Measure processing times of subcomponents of Uniquitous
  - Understand the performance bottlenecks in cloud game systems
- Experiment Setup
  - Hardware
    - 12 GB RAM, Intel 3.4GHz i7-3770, AMD Radeon HD 7700 series
  - Operating System
    - 64-bit Windows 7 Enterprise edition

System Parameters (2/6)

- Two Game Genres

Car Tutorial

AngryBots

- Eight Game Qualities

Quality Factor(Q)	1	5	10	20	40	60	80	100

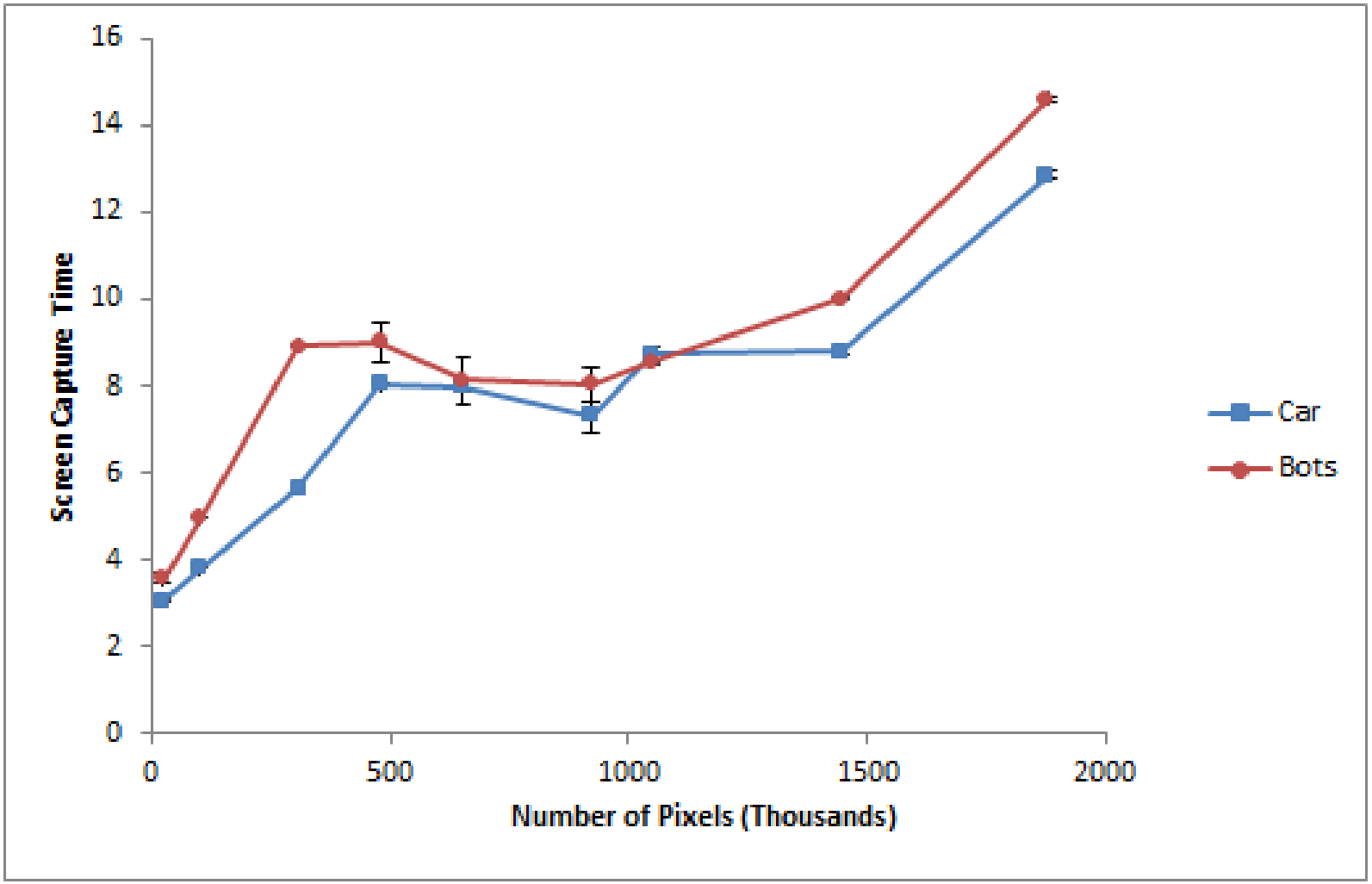
- Nine Game Resolutions

Game Resolution (R)	210 by 114	420 by 240	640 by 480	800 by 600	960 by 680	1280 by 720	1366 by 768	1680 by 860	1906 by 986

Methodologies (3/6)

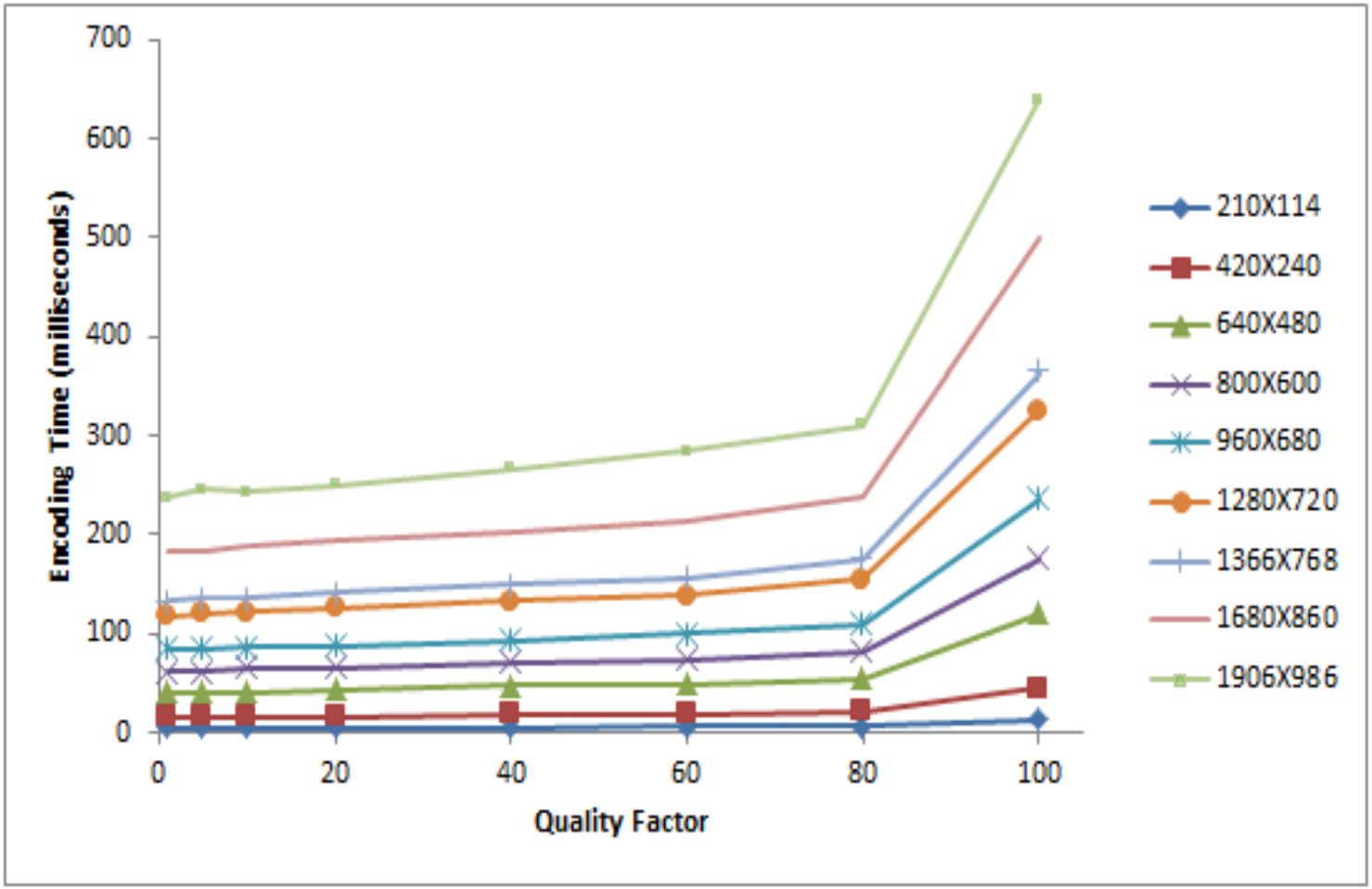
- Use Unity Pro Profiler to observe the CPU time of the component
  - Unity Project
  - Game Window
- Put time stamps in different places in the source code to measure time differences
  - Screen Capture
  - Image Encoding
  - Image Transmission
- Use Unix command “time” to get timing statistics for running the component
  - Audio Encoding & Transmission
- Experimental Results

Screen Capture (4/6)



Screen Capture Time at Nine Different Resolutions

JPEG Encoding (5/6)

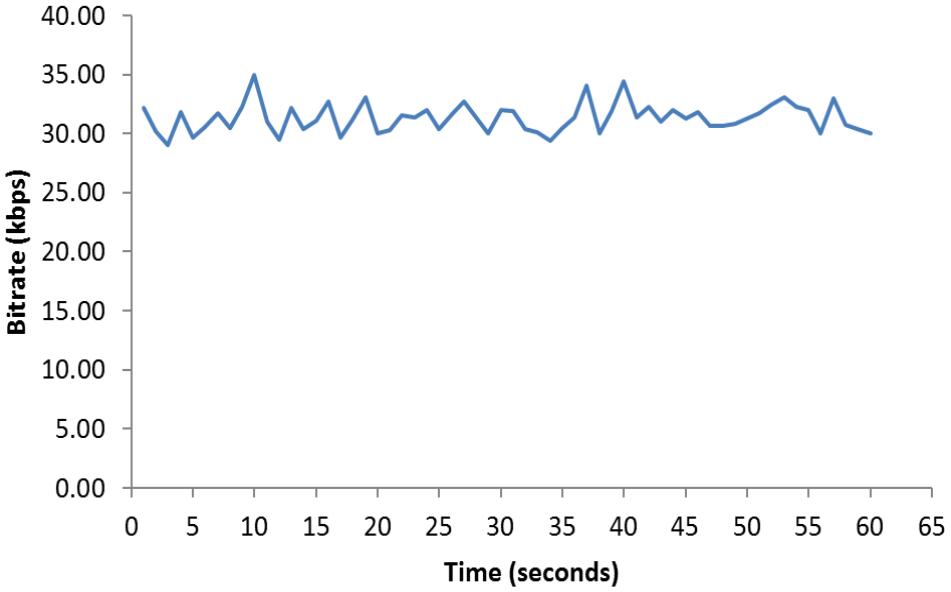


- Increase game image quality increases per frame encoding time
- Increase game resolution increases per frame encoding time

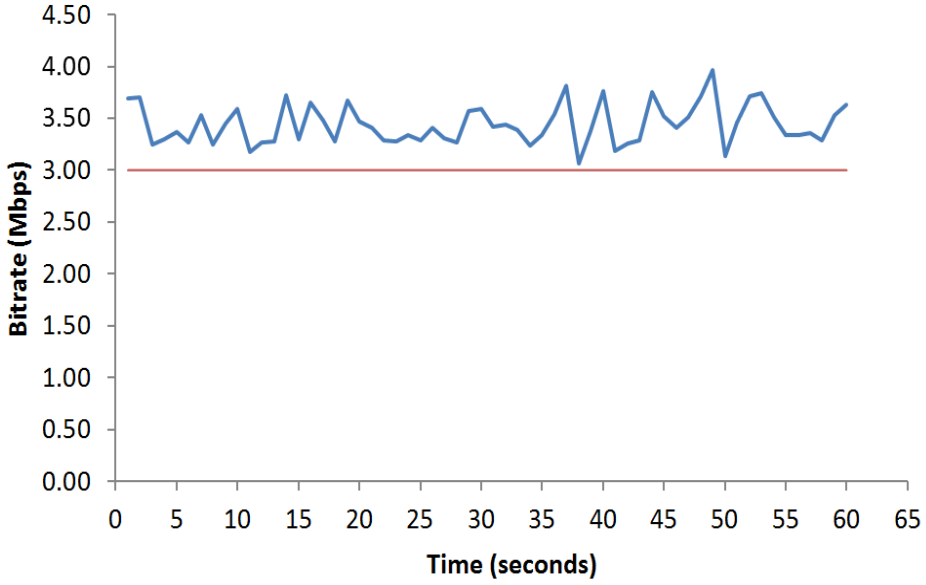
Per frame encoding time versus the JPEG Quality Factor at different Resolutions (Car Tutorial)

Network Estimate (6/6)

- R: 640×480, Q: 20, AngryBots
- Uplink bitrate is fluctuating around 32 kbps
- Downlink bitrate is fluctuating around 3.5 Mbps
- Uplink traffic is much smaller than the downlink traffic
- Similar to network traffic of OnLive [9]



Uplink network bitrate versus time



Downlink network bitrate versus time

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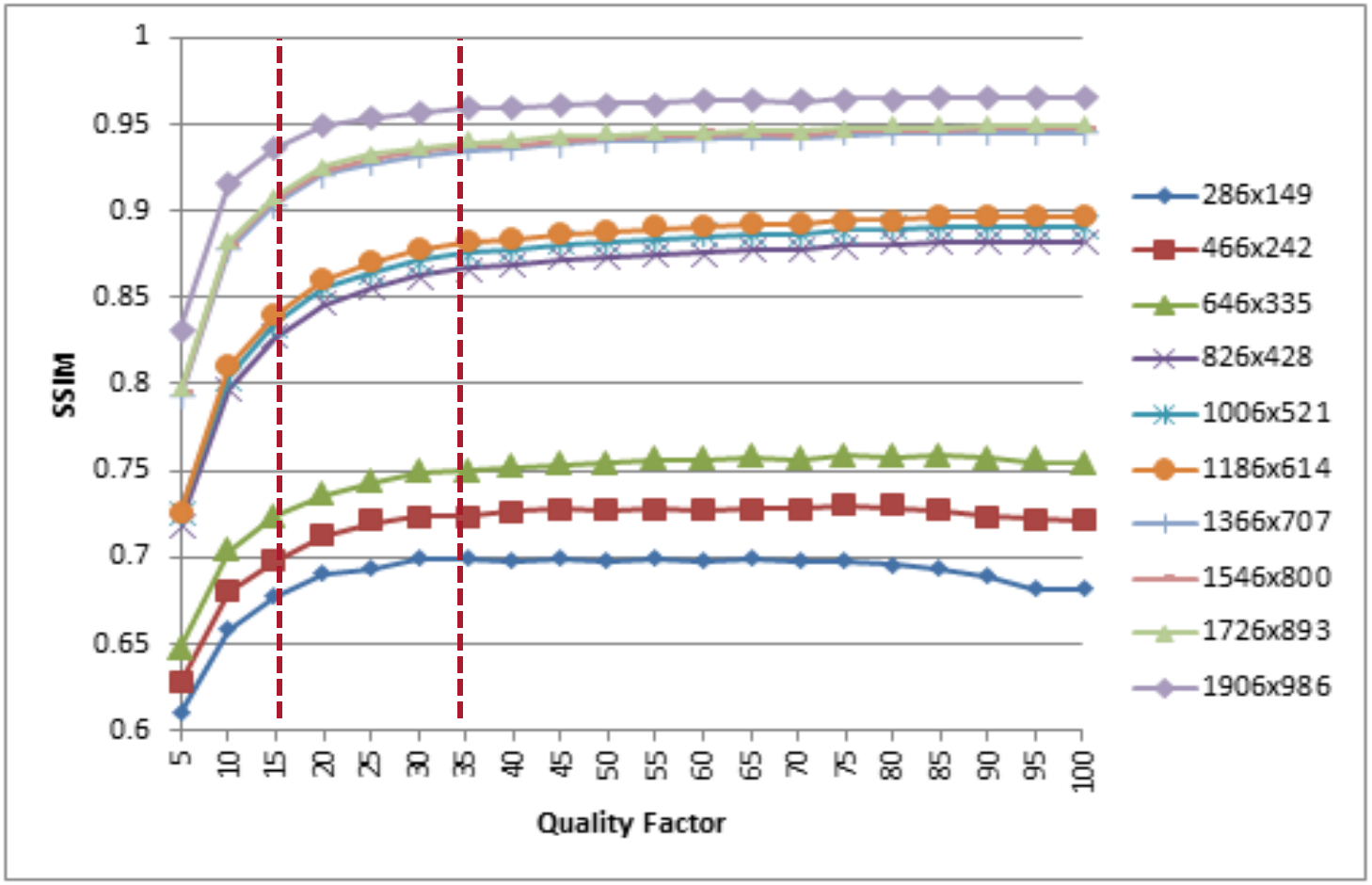
Macro Evaluation - Goal

- Analysis and Evaluation of performance of Uniquitous
  - Game Image Quality
  - Frame rate
- Predict Uniquitous performance under alternate configurations

Game Image Quality

- Compressed Image Samples
  - Original Image: game image from Car Tutorial
  - 200 images with 20 compression ratios and 10 resolution levels
- Objective Visual Quality Measurement
  - Peak Signal Noise Ratio (PSNR)
  - Structural Similarity Index (SSIM)
- Experiment Setup
  - Same as the Micro Evaluation

Experimental Results



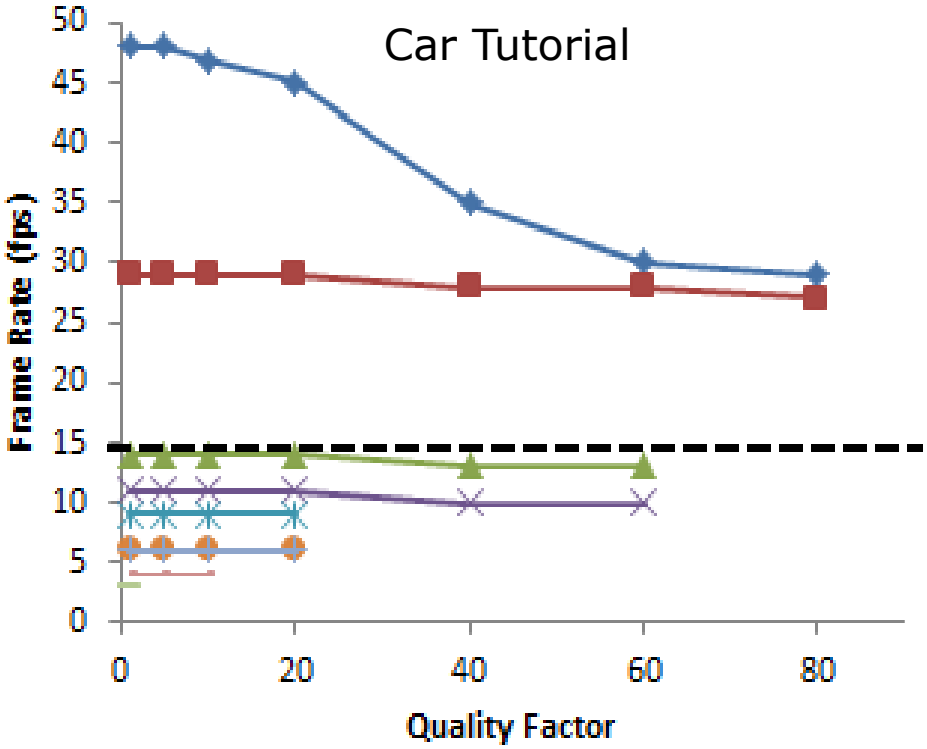
- Marked increase from 1 to 15
- Modest increase from 15 to 35
- Recommended quality factor: 15 to 35

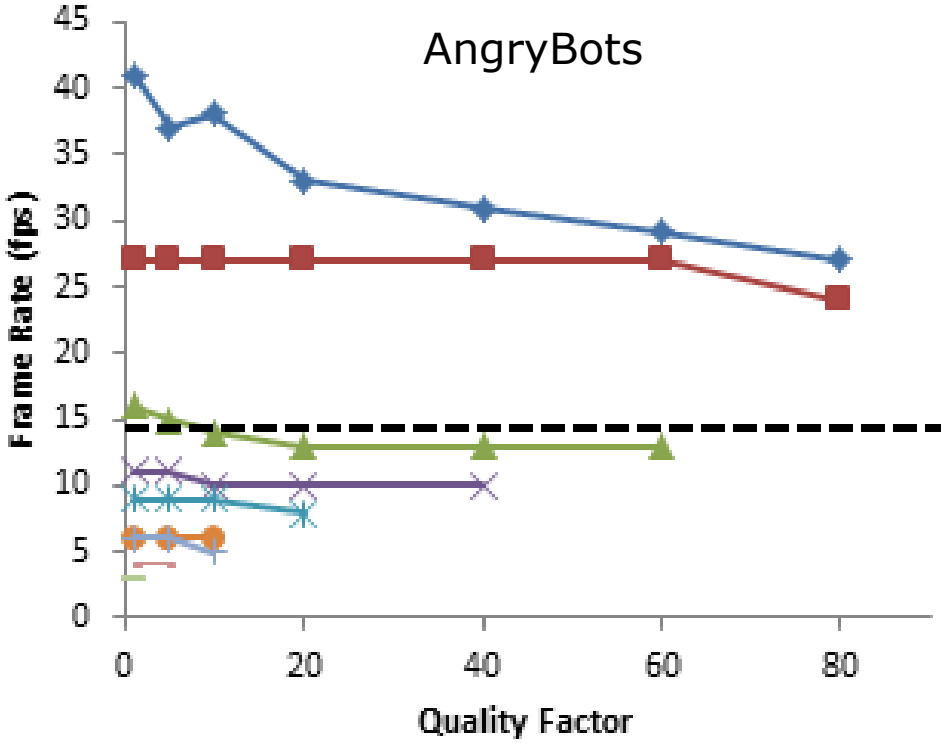
SSIM values versus the JPEG quality factor among different game resolutions

Frame Rate

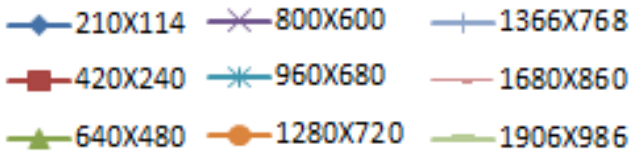
- Data Samples Selection
  - Each data sample contains a different setting of JPEG encoding quality factor and resolution
  - 44 data samples for the Car Tutorial
  - 37 data samples for the AngryBots
- Frame Rate Computation
  - Use time stamps to measure frame intervals
  - Calculate the inverse of the average interval value
- Experiment Setup
  - Same as the Micro Evaluation

Experimental Results

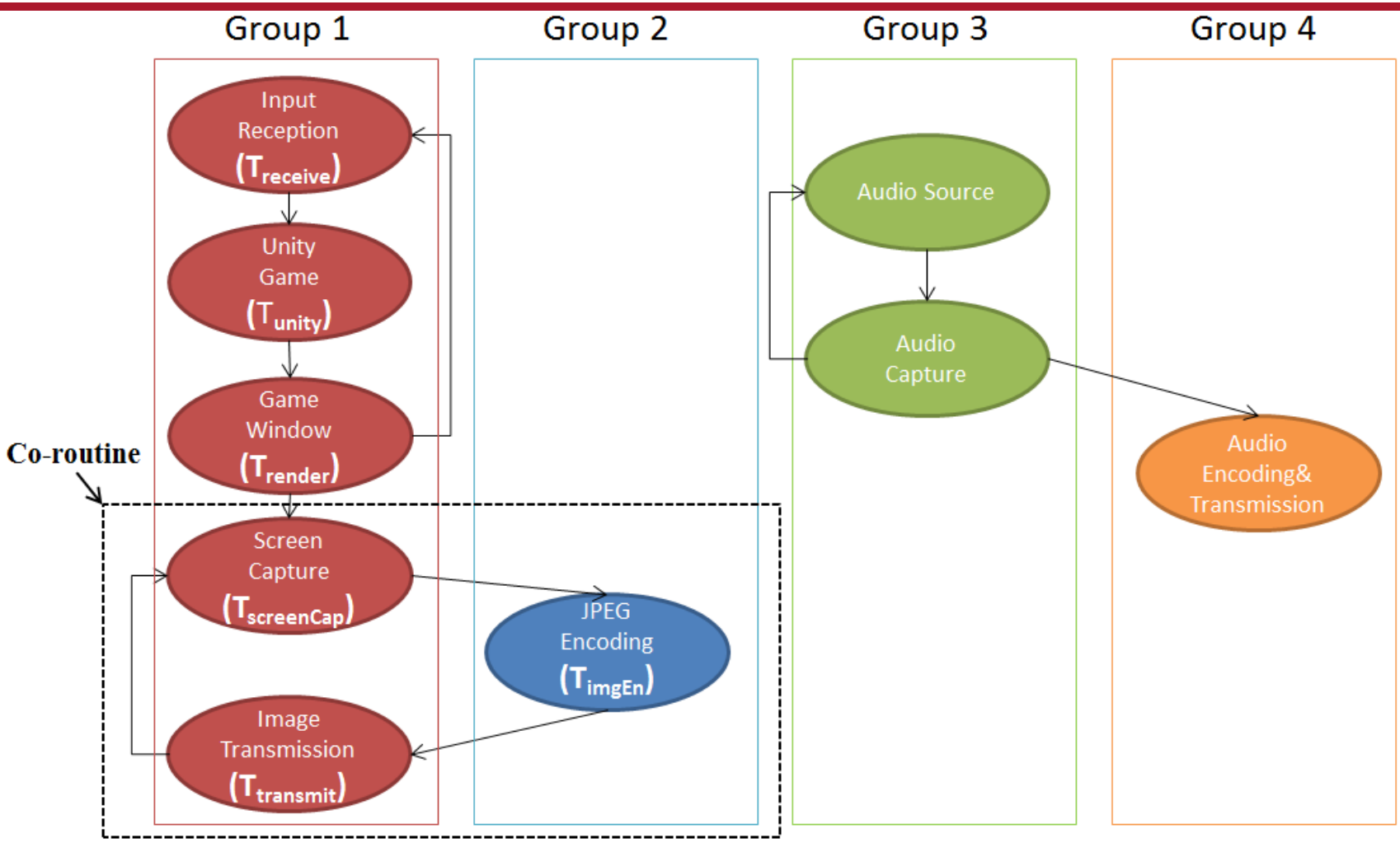




- Increase the image quality or the resolution degrades the frame rate
- Recommended min frame rate: 15 fps [8]
- Recommended resolution: 640x480



Predicting Frame Rate (1/3)



Parallel working structure of Uniquitous Server

Predicting Frame Rate (2/3)

- Derive the Model Predicting the Frame Rate on the Server

$F = 1/T$

$T = \text{Max}(T_{1'}, T_2) + T_{screenCap} + T_{transmit}$

$T_{1'} = T_{unity} + T_{render}$

$T_2 = T_{imgEn}$

If $T_2 = \text{Max}(T_{1'}, T_2)$,
Then $T = \text{Max}(T_{1'}, T_2) + T_{screenCap} + T_{transmit} + T_{error}$
($T_{error} \in [0, 20]$)

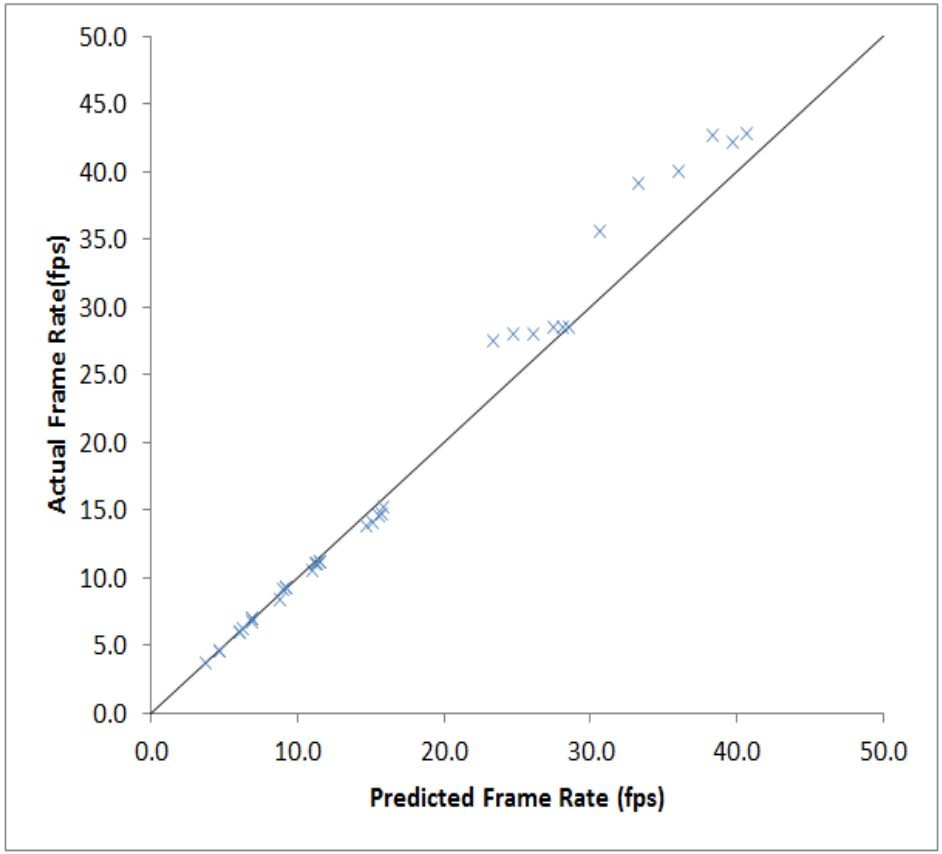
$T_{1'}$: processing time of the first three components of Group 1
T_2 : processing time of Group 2
T: frame interval
F: predicted frame rate
T_{error} : error term

Predicting Frame Rate (3/3)

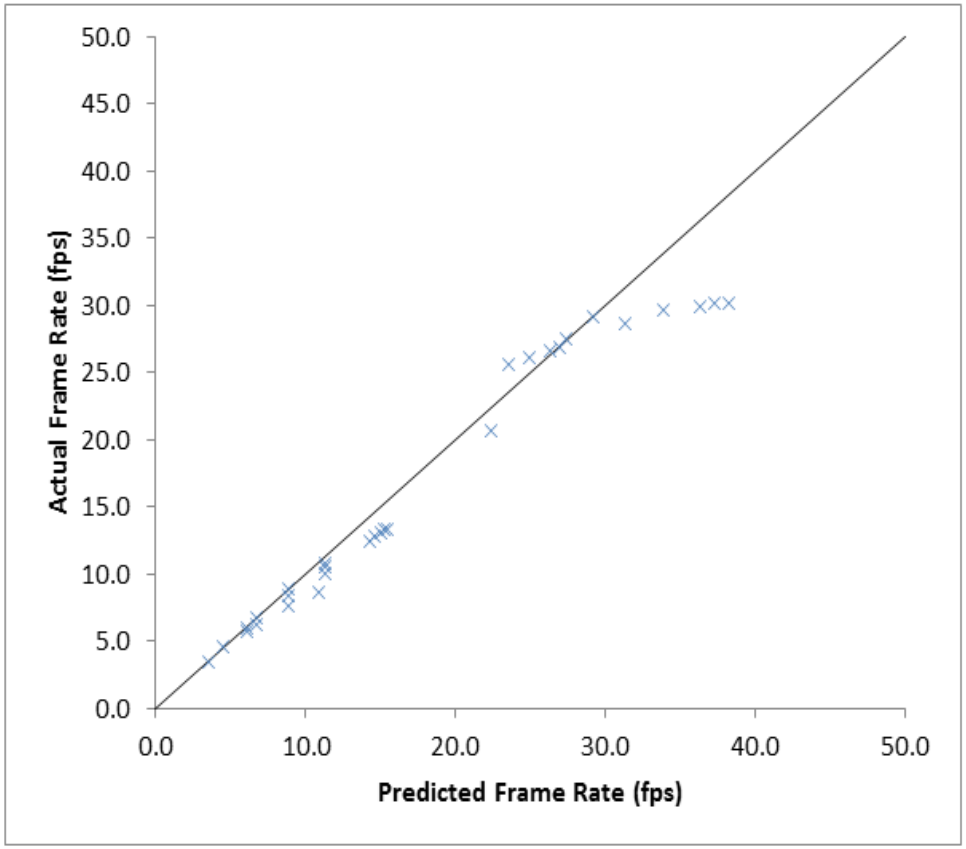
- Build the model to predict the client frame rate
  - Based on game Resolution (R), JPEG encoding quality factor (Q)
  - Weka Linear regression classifier (10-fold cross validation)
    - Car Tutorial: $F_{predict} = 1 / (0.1348 \times R + 0.118 \times Q + 21.0)$
    - AngryBots : $F_{predict} = 1/ (0.1361 \times R + 0.1224 \times Q + 22.5)$
  - Validation results

Validation Results

- Both models predict well
- Car: correlation coefficient is 0.995, average error percentage is 4.79%.
- Bots: correlation coefficient is 0.981, average error percentage is 9.47%.



Car Tutorial



AngryBots

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Conclusions

- Uniquitous is a system for cloud game research or cloud game development.
- Uniquitous architecture: three entities and three data flows.
- The image encoding process is the processing bottleneck – processing time increases with game image quality and resolution.
- Frame rate is inversely proportional to both the game quality and the resolution.
- Recommended quality factor range for Uniquitous: 15-35 , to maintain a good frame rate.
- Recommended resolution for Uniquitous: no larger than 640x480, to achieve a frame rate of 15 fps or higher.
- Models can be used by developers to choose settings for good gameplay performance

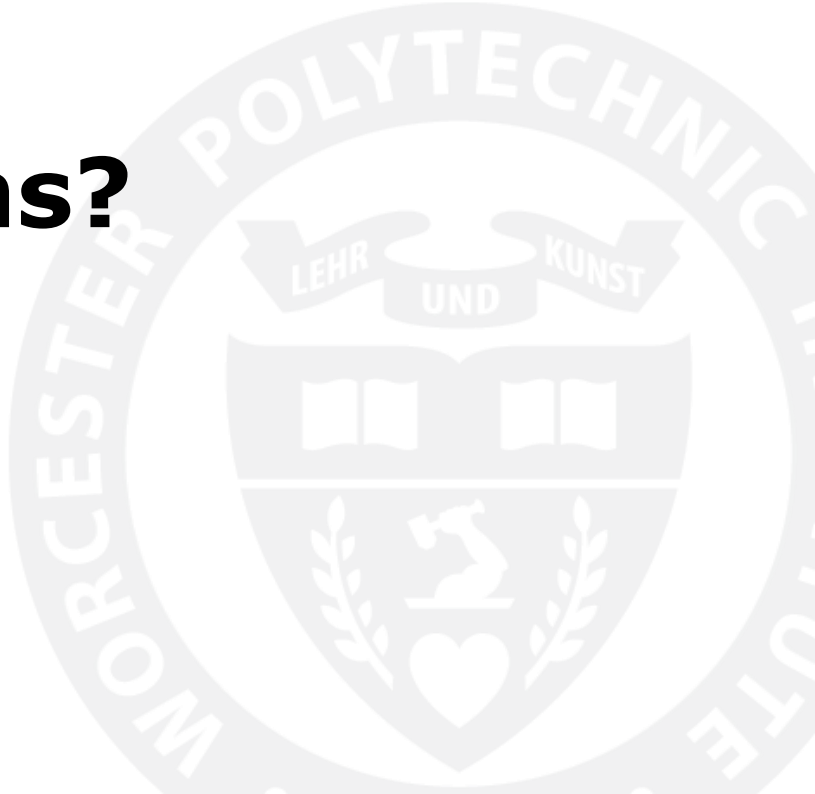
Future Work

- Performance improvement
  - Increase the achieved frame rate
  - Support the transmission of frames of higher game quality and higher resolution

- Areas recommended for exploring with Uniquitous
  - Test with more games to include three general game genres [10]
  - Extend and deploy Uniquitous on mobile devices to evaluate its performance

Thank You!

Questions?



References

[1] Distribution and monetization strategies to increase revenues from Cloud Gaming: http://www.cgconfusa.com/report/documents/Content-5minCloudGamingReportHighlights.pdf, Date accessed: 05/01/2014

[2] Sony buys Gaikai cloud gaming service for $380 million http://www.engadget.com/2012/07/02/sony-buys-gaikai/, by Sharif Sakr on July 2nd 2012, at 2:55:00 am ET

CES 2014: Gaikai becomes PlayStation Now, streaming games to just about everything

http://www.extremetech.com/gaming/174236-ces-2014-gaikai-becomes-playstation-now-streaming-games-to-just-about-everything ,by James Plafke on January 7, 2014 at 3:09 pm

[3] Minimum system requirement for OnLive: https://support.onlive.com/hc/en-us/articles/201229050-Computer-and-Internet-Requirements-for-PC-Mac-, Date accessed: 11/06/2014

[4] Unity Fast Facts: http://unity3d.com/company/public-relations, Date accessed: 05/01/2014

[5] I. Foster, Y. Zhao, I. Raicu, and S. Lu, "Cloud Computing and Grid Computing 360-Degree Compared," *In Proceedings of Workshop on Grid Computing Environments (GCE)*, pp. 1, January 2009.

[6] C. Huang, C. Hsu, Y. Chang, and K. Chen. "Gaminganywhere: An open cloud gaming System," *in Proceedings of the ACM Multimedia Systems Conference (MMSys'13)*, Oslo, Norway, February 2013.

[7] Yu-Chun Chang, Po-Han Tseng, Kuan-Ta Chen, and Chin-Laung Lei." Understanding the Performance of Thin-Client Gaming", in Proceedings of *IEEE CQR*, May 2011.

[8] Mark Claypool and Kajal Claypool. "Perspectives, Frame Rates and Resolutions: It's all in the Game", in Proceedings of the *4th ACM International Conference on the Foundations of Digital Games (FDG)*, Florida, USA, April 2009.

[9 M. Claypool, D. Finkel, A. Grant and M. Solano, "On the performance of OnLive Thin Client Games", in *Multimedia System Journal (MMSJ) – Network and Systems Suppport for Games*, Denver, Colorado, USA, Octorber 2013.]

[10] M. Claypool and K. Claypool, "Latency can kill: precision and deadline in online games," in *Multimedia Systems Conference (MMSys)*, Phoenix, Arizona, USA, February 2010.

[11] What is cloud computing: http://searchcloudcomputing.techtarget.com/definition/cloud-computing Date accessed: 11/06/2014