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Perceptually Optimised Video Compression

A Marie Skłodowska-Curie Initial Training Network

This project has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement no 608231

# Naturalistic measurement of perceived video quality by measuring disruptions in free-viewing gaze patterns :

## **Case study of Interactive streaming**

**Yashas Rai, Gene Cheung, and Patrick Le Callet, in *Image Processing, 2016. ICIP 16. Proceedings. (submitted)*]**

# Agenda

- Why good quality estimation?
- Measuring quality naturalistically
- Modelling the Interactive Gaze System
- The GMM based HMM model
- Prediction Performance of the model
- Content dependence

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# Need for good quality metrics

- Compress multimedia in such a way that distortions are cleverly embedded in the invisible areas
  - Reduced size implies less storage space on cloud -> Better profits!
  - More storage space for user-content on handheld devices!
- Efficient representation for faster transmission (broadcast and streaming)
  - Channels now approach Shannon limit whereas computing power is still increasing in a Moore Scale

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# Ground Truth quality of a video

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- Quality assessment typically involves the subject examining a video sequence of several seconds and providing a quality score.
  - He is often searching for distortions in a very intricate manner.

- Attention Modulation in V4  (Response gain model):
  - Response to unattended stimulus reduces even though its within the receptive field – Neuronal firing is 51% greater with attention [1]
  - Contrast detection thresholds 20%,  Contrast Discrimination 40-50%, Orientation Discrimination 70% lower [1]
  - Attention influences motion processing by enhancing processing of relevant and suppressing the processing or irrelevant objects [2]
  - Tracking in the fovea task combined with a Number recognition in periphery – More is the attention to the  foveal task, more is the drop in performance of the peripheral task [3]

- **Do we examine videos in a similar manner when we freely watch videos at home?**


[1] J. Moran and R. Desimone, "Selective attention gates visual processing in the extrastriate cortex," *Science*, vol. 229, no. 4715, pp. 782–784, 1985.
[2] J. Braun and B. Julesz, "Withdrawing attention at little or no cost: detection
[3] B. Khurana and E. Kowler, "Shared attentional control of smooth eye movement and perception," *Vision research*, vol. 27, no. 9, pp. 1603–1618, 1987.



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# Subjective Experiment : Gaze contingency

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- Alter the quality in the visual peripery in real-time in accordance to gaze position.
- HEVC distortions
  - 4 different Quantizations
  - Para and Peri-Fovea (5.09 and 10.9)

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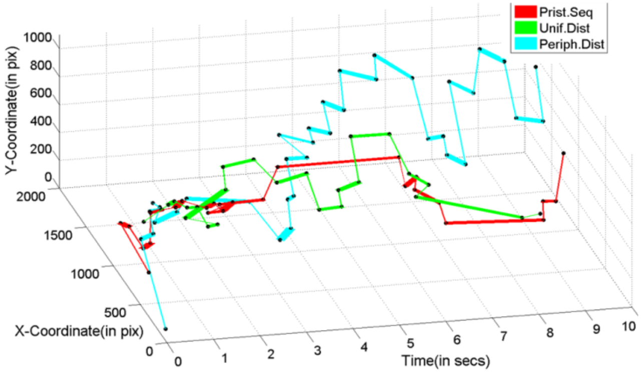
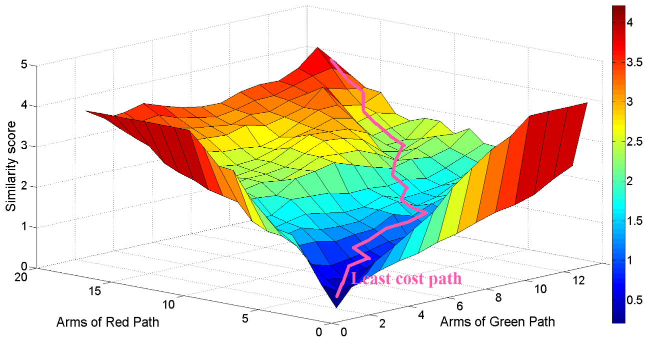
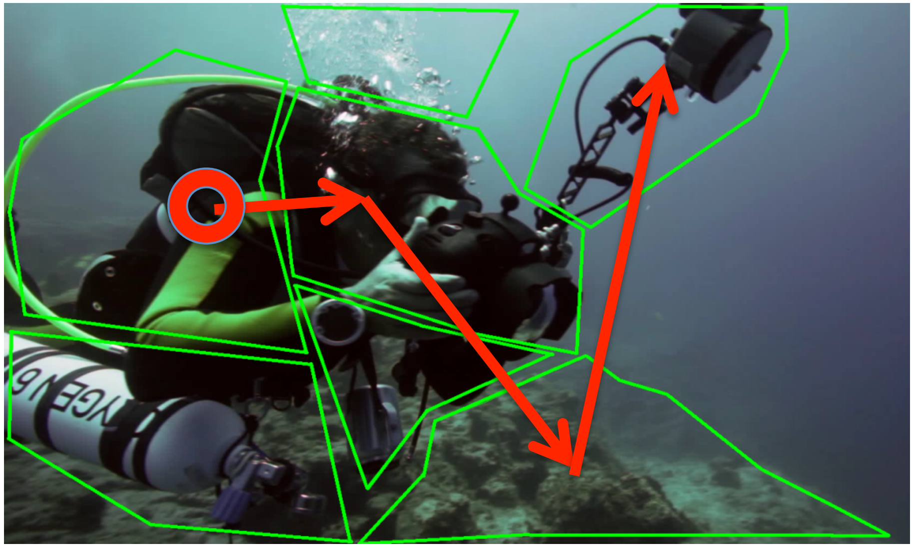
# Measuring Disruptions

- Vector Similarity: measuring the difference in scan-path trajectories
- Comparing object transitions : **D-B-B-C-C-C-A**, **D-D-C-B-A** followed by Levenshtein similarity of string patterns.



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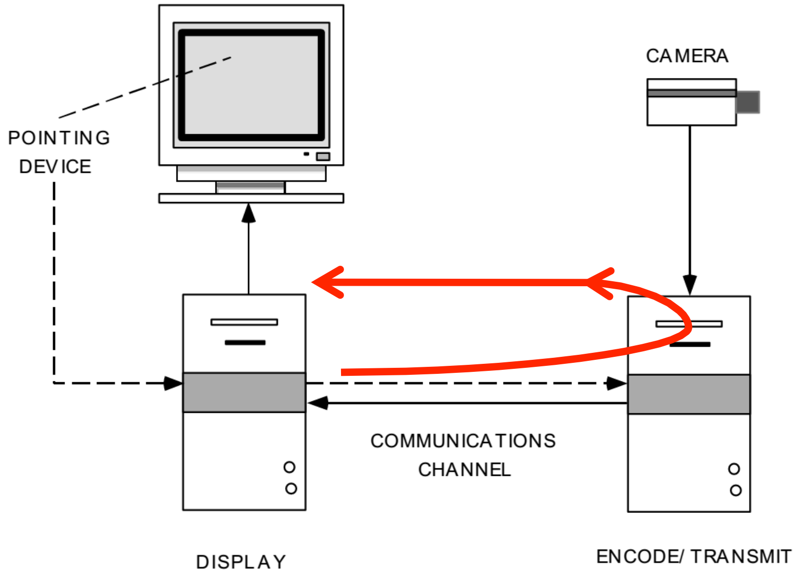
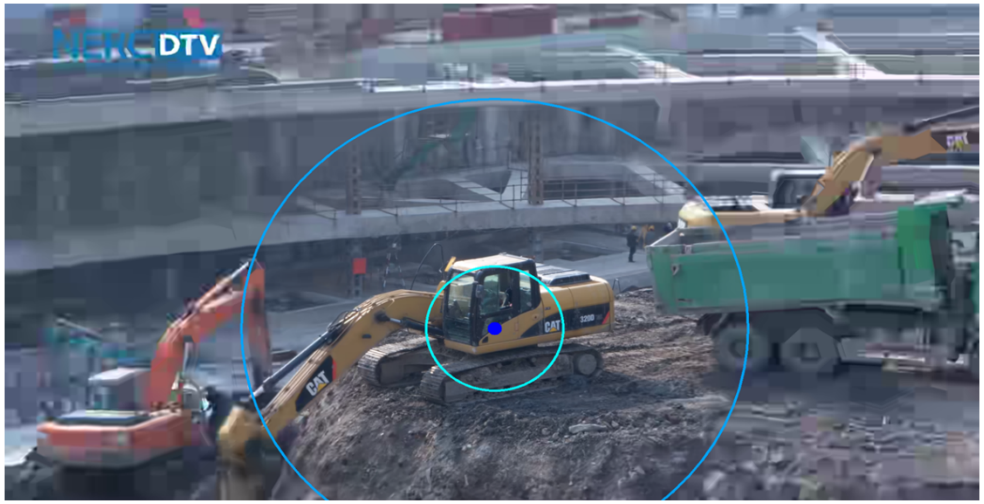
# Interactive Video Streaming

- A reverse channel that transmits gaze data from the client end
- Virtual Reality, Panoramic Displays
- Practical considerations
  - Availability of a camera at the client end
  - Network delay
  - Real-time encoding

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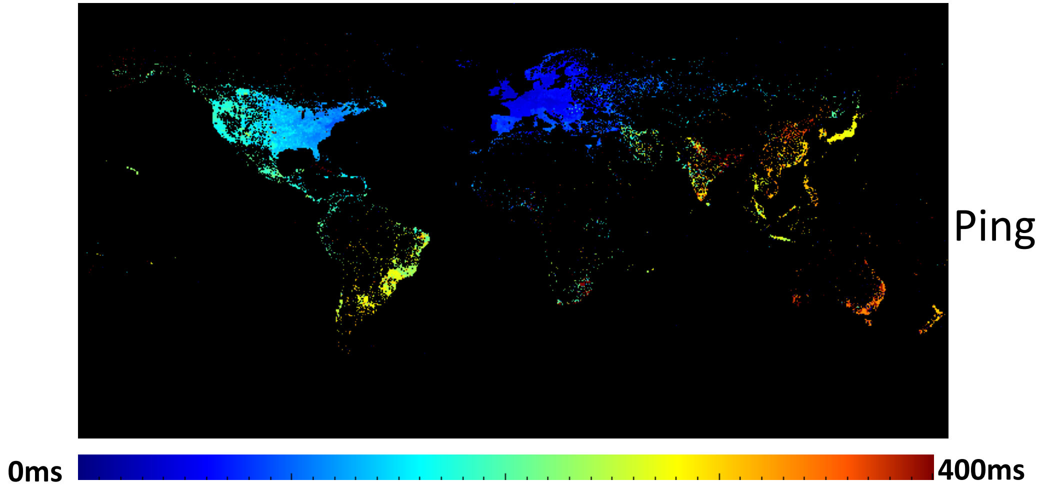
# RTT delay

- Round Trip Time: The time from which the user makes a head movement till the time the actual update happens on the display
  - Eye Tracker Latency [<2 ms]
  - Network Propagation Delay (x2) [180-190 ms]
  - Encoding Delay [10 ms]
  - Display Refresh Rate [8.3 ms]
- Considering wide geographies, we may consider the latency to be ~200 ms




Ping times from Oxford [folk.uio.no]

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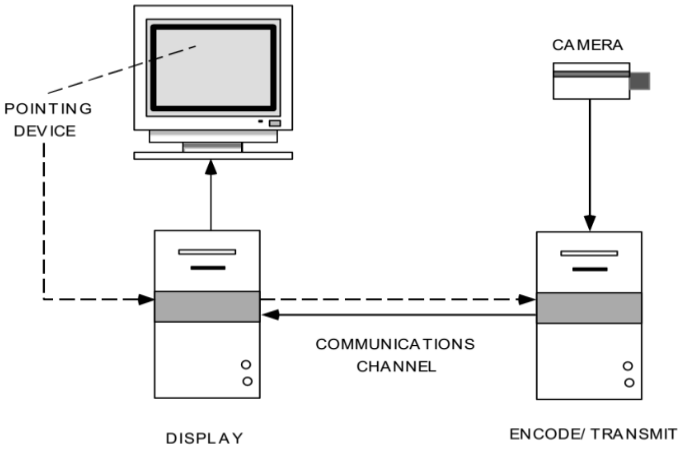
# Goals of the research

- Does the presence of peripheral HEVC artefacts/ uniform HEVC artefacts alter this prediction accuracy?
    - **Same gaze model designed for the pristine sequence works here, as well?**
    - **HEVC artefacts introduce new Bottom-up effects?**

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# Predicting future gaze locations

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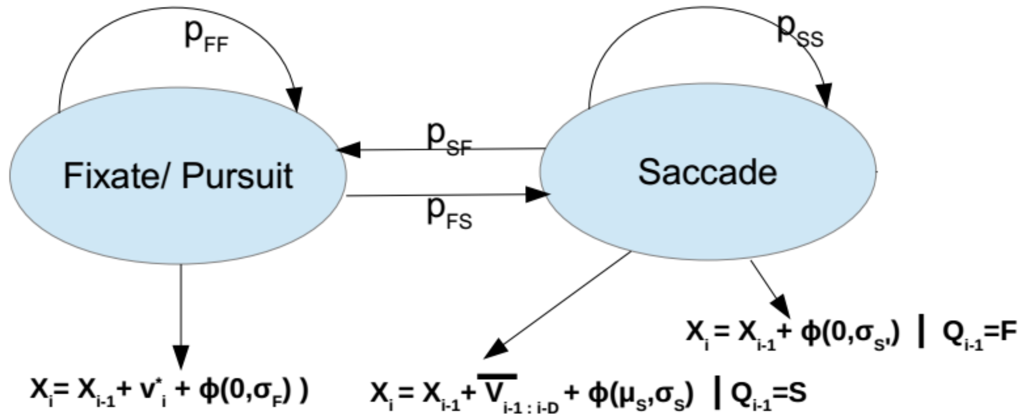


- Types of Eye-movements
  - Saccade – Fast movement of the eye to attend to a different region
  - Fixate – Continue to gaze at the same position for detailed examination
  - Pursuit – Follow the trajectory of a moving object with the eyes
- Terminologies:
  - $X_i$ and $X_{i-1}$ are the (x,y) spatial locations
  - $Q_i$ and $Q_{i-1}$ are the hidden states
  - $V_i$ is determined by the motion of the maximum likelihood object
  - $V_{i-1:i-D}$ indicates the average of the previous saccade speeds
  - $\Phi()$ is the normal noise

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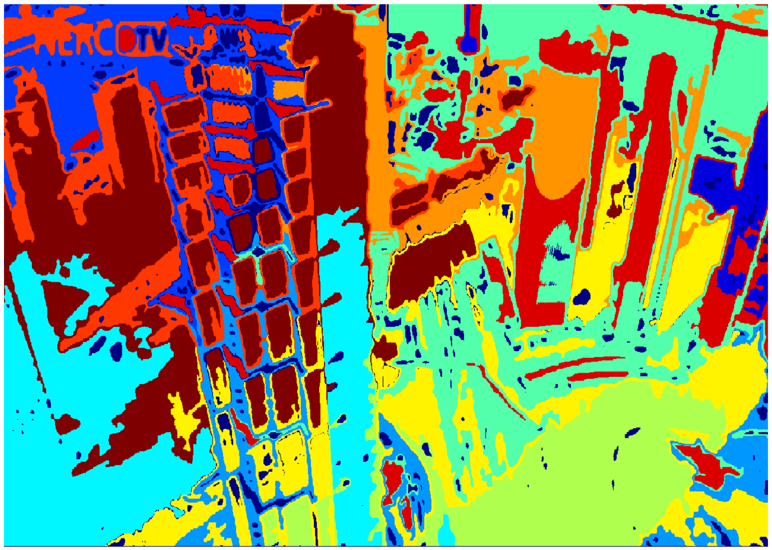
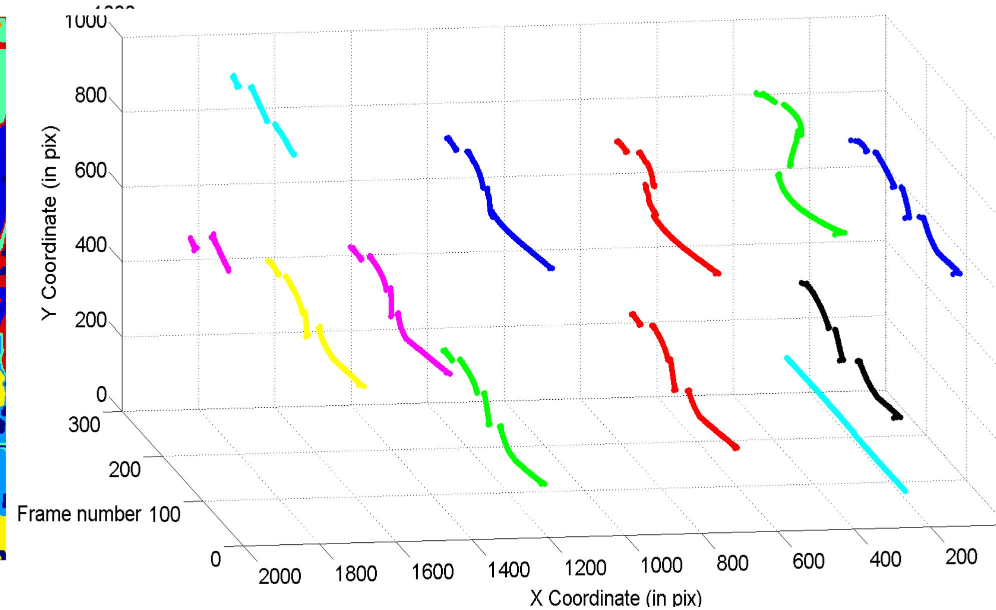
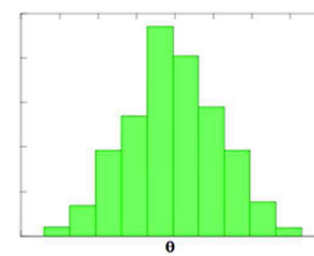
# Gaze prediction: Tracking objects under motion






- Segmenting the image into discrete super-pixels using texture and color based super-pixelation.
- Motion consistency analysis in each region




[Anil K Jain and Farshid Farrokhnia, "Unsupervised texture segmentation using gabor filters," in *Systems, Man and Cybernetics, 1990. Conference Proceedings., IEEE International Conference on*. IEEE, 1990, pp. 14–19.]
[M.A. Hasan, Min Xu, Xiangjian He, and Changsheng Xu, "CAMHID: Camera motion histogram descriptor and its application to cinematographic shot classification," *Circuits and Systems for Video Technology, IEEE Transactions on*, vol. 24, no. 10, pp. 1682–1695, Oct 2014]

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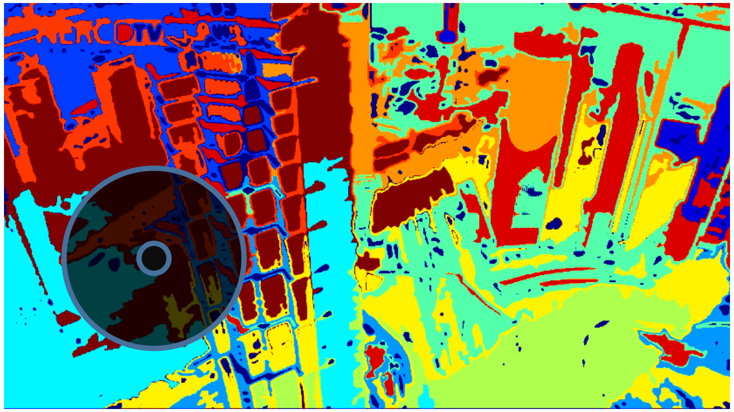
# Determining the velocity $v_i$* of pursuit

- Due to the noise in the gaze data, we do not really know which object the user is actually tracking
- Consider all the objects within a radius of 2 degrees and take the one that maximizes the posterior probability

$$P_Q(X_{i+1}|X_i) = \max_{v_i \in M(X_i)} f_{\sigma_{F^2}}(X_{i+1} - X_i - v_i)$$

$$v_i^* = arg \max_{v_i \in M(X_i)} f_{\sigma_{F^2}}(X_{i+1} - X_i - v_i)$$



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# Parameter estimation by training with real gaze data

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- Gaze data from 30 observers
  - Estimate transition probabilities $[p_{FF}, p_{FS}, p_{SF}, p_{SS}]$
  - Estimate the Gaussian processes $[\sigma_F, \sigma_S, \sigma_{S'}]$
  - Estimate the state probabilities $[p_F, p_S]$
- Offline Learning: Baum Welch Forward-Backward propagation
- Online Learning: Forward only propagation

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# LDS based prediction of future locations

$$\mathbf{Y}_n = \underbrace{\begin{bmatrix} 1 & (1-\beta) \\ 0 & (1-\beta) \end{bmatrix}}_{\mathbf{F}_n} \mathbf{Y}_{n-1} + \underbrace{\begin{bmatrix} \beta c_1 \ldots \beta c_Z \\ \beta c_1 \ldots \beta c_Z \end{bmatrix}}_{\mathbf{B}_n} \underbrace{\begin{bmatrix} v_{n-1}^1 \\ \vdots \\ v_{n-1}^Z \end{bmatrix}}_{\mathbf{u}_n}$$

- Perform prediction only if in current as well as RTT seconds in future we have high chances of remaining in Fixation state
- $Y_n$ contains the position and velocity vectors.
- $V^Z_{n-1}$ are the motion vector of surrounding pixels, each weighted by $c_z$
- This is performed repeatedly, RTT samples into the future

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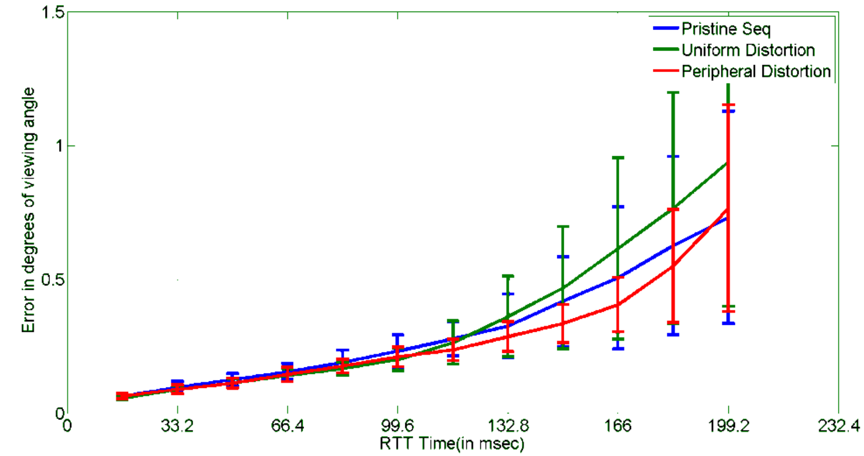
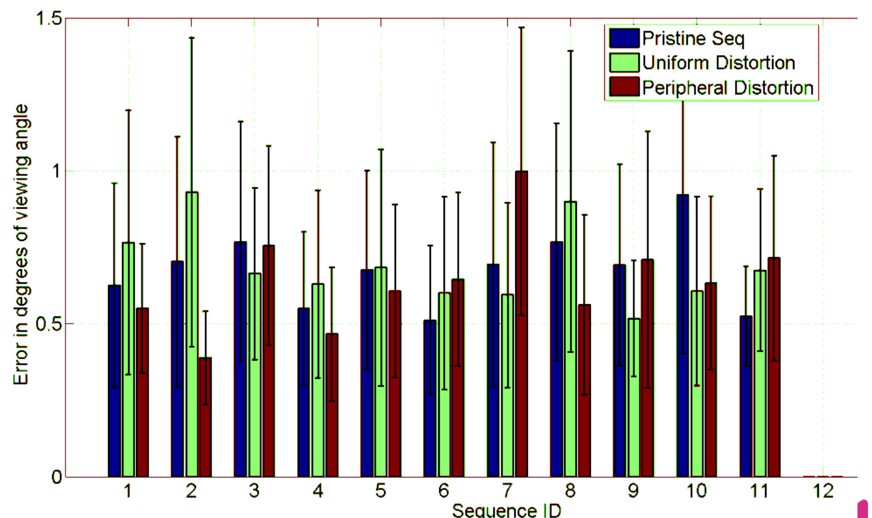
# Prediction performance

- Peripheral or uniform distortions have no special effect on gaze predictability!
- The model trained for the pristine case could also predict these cases well!
- Can perform the prediction to within 1.5 degrees of viewing angle error (200ms)

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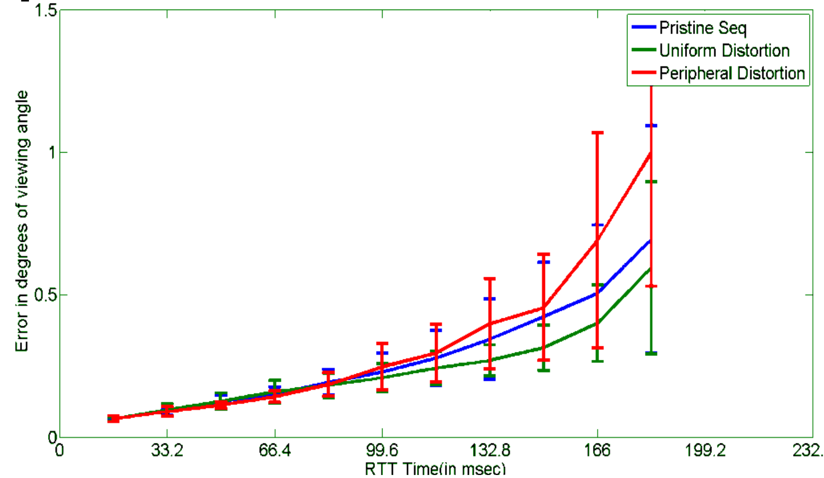
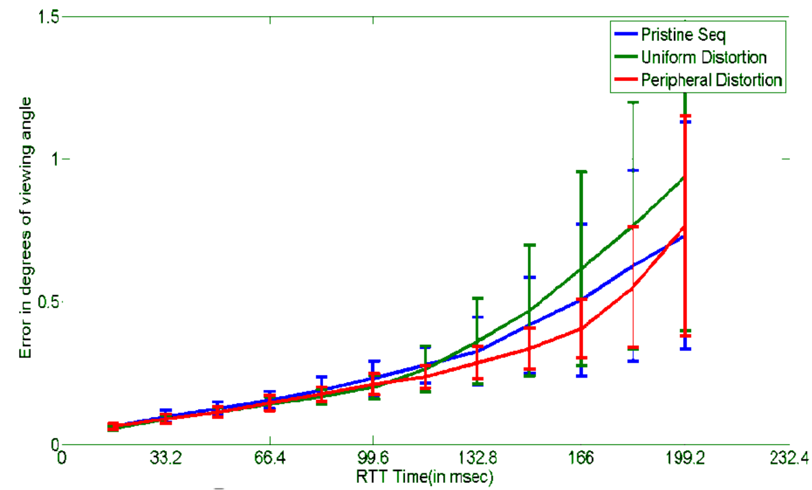
# Prediction by sequence type

- Measuring temporal activity with MC-Saliency maps
- High temporal activity -> High prediction error for peripheral distortions
- Low temporal activity -> High prediction error for uniform distortions




Diver (MC-Saliency=$216 \times 10^{-4}$)




Construction-Field (MC-Saliency=$1.88 \times 10^{-4}$)

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# Statistical test for verification

- Check how well the Kalman predictor predicts the gaze locations (Euclidean error)
- Is this error significantly higher, while predicting gaze data in case of peripheral / uniform distortion?

**Table II**

| | | $RTT = 100ms$ | | $RTT = 200ms$ | |
|---|---|---|---|---|---|
| Seq.ID | | Pristine vs Unif.Dist | Pristine vs Periph.Dist | Pristine vs Unif.Dist | Pristine vs Periph.Dist |
| 1 | Construction Field | 0.23 | 0.69 | 0.78 | 0.86 |
| 2 | Fountains | 0.26 | 0.25 | 0.44 | 0.10 |
| 3 | Library | 0.48 | 0.53 | 0.69 | 0.26 |
| 4 | Resid. Building | 0.42 | 0.59 | 0.50 | 0.61 |
| 5 | Tall Buildings | 0.61 | 1.00 | 0.71 | 0.62 |
| 6 | NTIA-Redgold | 0.83 | 0.42 | 0.83 | 0.39 |
| 7 | Diver | 0.64 | 0.27 | 0.42 | 0.84 |
| 8 | Lobsters | 0.42 | 0.50 | 0.18 | 0.67 |
| 9 | Evening Walk | 0.53 | 0.83 | 0.33 | 0.54 |
| 10 | Traffic Building | 0.07 | 0.09 | 0.10 | 0.13 |
| 11 | NTIA-Purple | 0.17 | 0.16 | 0.81 | 0.43 |
| 12 | Tree Shade | - | - | 0.51 | 0.99 |

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# Key take-aways

- Peripheral as well as uniform distortions do not affect the prediction capabilities of the model
- Such a model maybe safely used for gaze prediction in interactive streaming systems
- Gaze disruption measurement can be used to test the annoyance of video distortions in a naturalistic manner!

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# Thank-You / Questions?

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