DGaze: CNN-Based Gaze Prediction in Dynamic Scenes

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Project URL: cranehzm.github.io/DGaze

Outline

- Background
- Related Work
- DGaze Model
- Limitations and Future Work

Eye Tracking Technology

Eye Tracking Technology[1]

[1] https://www.7invensun.com/

Background

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Eye Tracking Technology

- Neuroscience & Psychology
- Industrial Engineering
- Marketing & Advertising
- Computer Science
- .....

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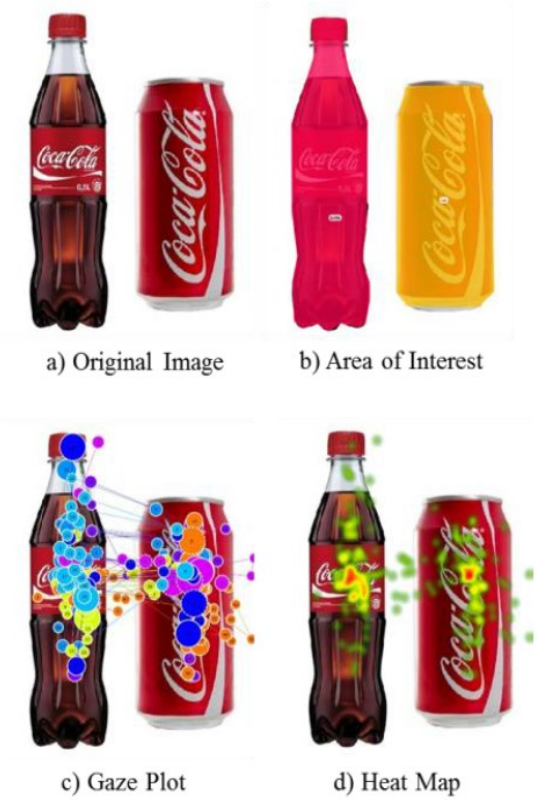
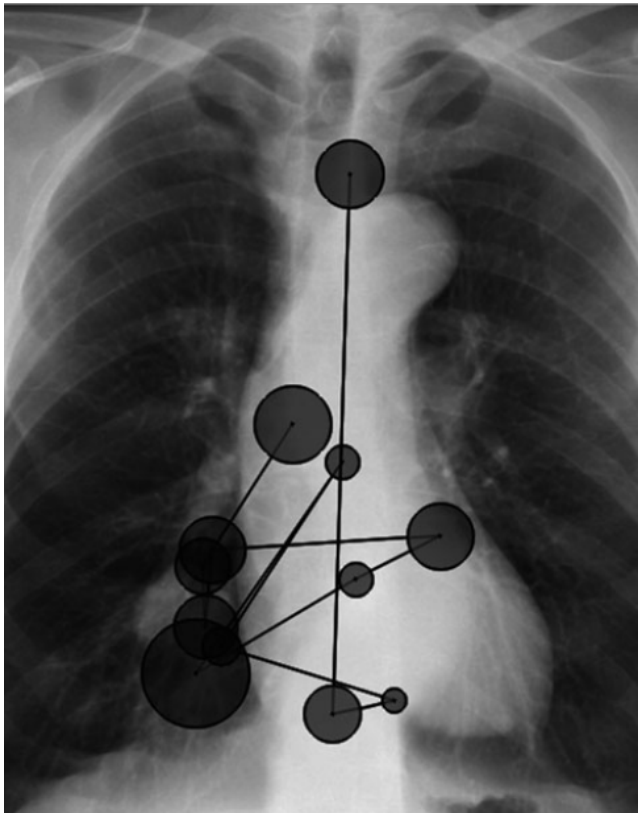
Eye Tracking Technology





Marketing Strategy Analysis
[Zamani et al. 2016]

Cognitive Research
[Kiefer et al. 2017]

Medical Education
[Kok et al. 2017]

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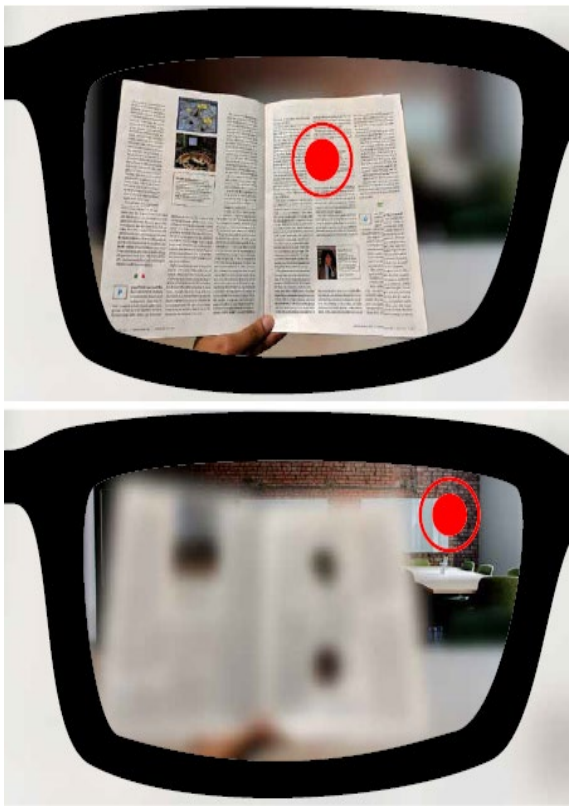
Eye Tracking Technology

Gaze-based Interaction
[Pfeiffer et al. 2008]

Collaborative System
[Zhang et al. 2017]



Gaze-contingent Eyeglasses
[Padmanaban et al. 2019]

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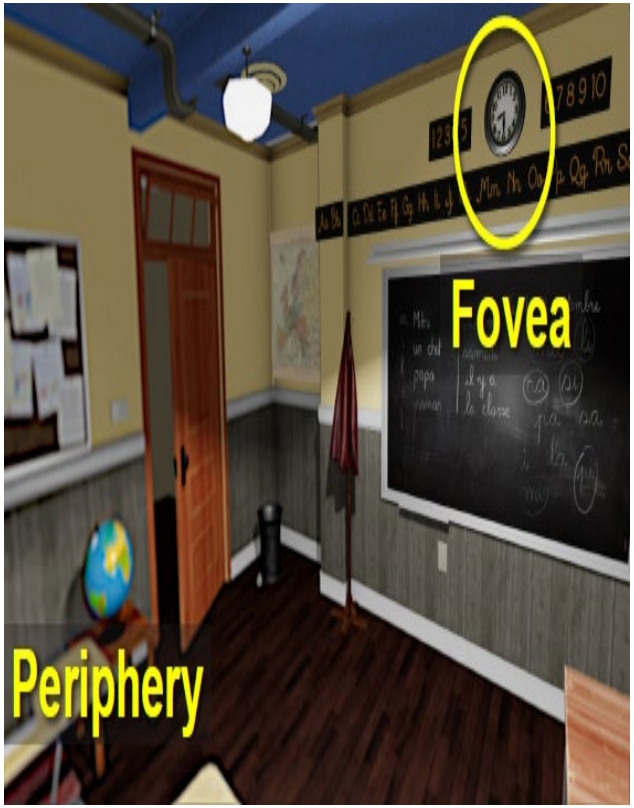
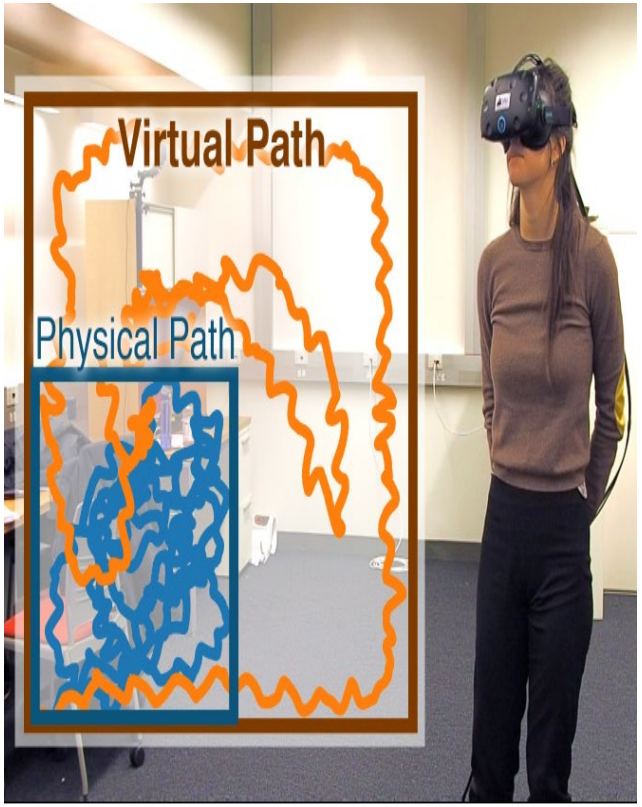
Eye Tracking in Virtual Reality



Gaze-contingent Rendering
[Patney et al. 2016]



Redirected Walking
[Sun et al. 2018]

Gaze Behavior Analysis
[Alghofaili et al. 2019]

Solution to Eye Tracking in VR

Hardware-based Solution

Eye Tracker[1]

- Accurate ✓
- Currently Expensive ✗
- Not Widely Available ✗
- May Need Calibration ✗
- Cannot Predict Future Gaze Position ✗

[1] https://www.7invensun.com/

Motivation of Our Work

- Propose a **software-based** eye tracking solution in VR that only employs information from the VR system (does not utilize eye trackers)

Our Goals

- Analyze users' gaze behaviors in virtual reality
- Predict users' gaze positions based on the characteristics of users' gaze

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Salient Object Detection

Top: Original Images[1]; Bottom: Salient Objects [1]

[1] https://mmcheng.net/msra10k/

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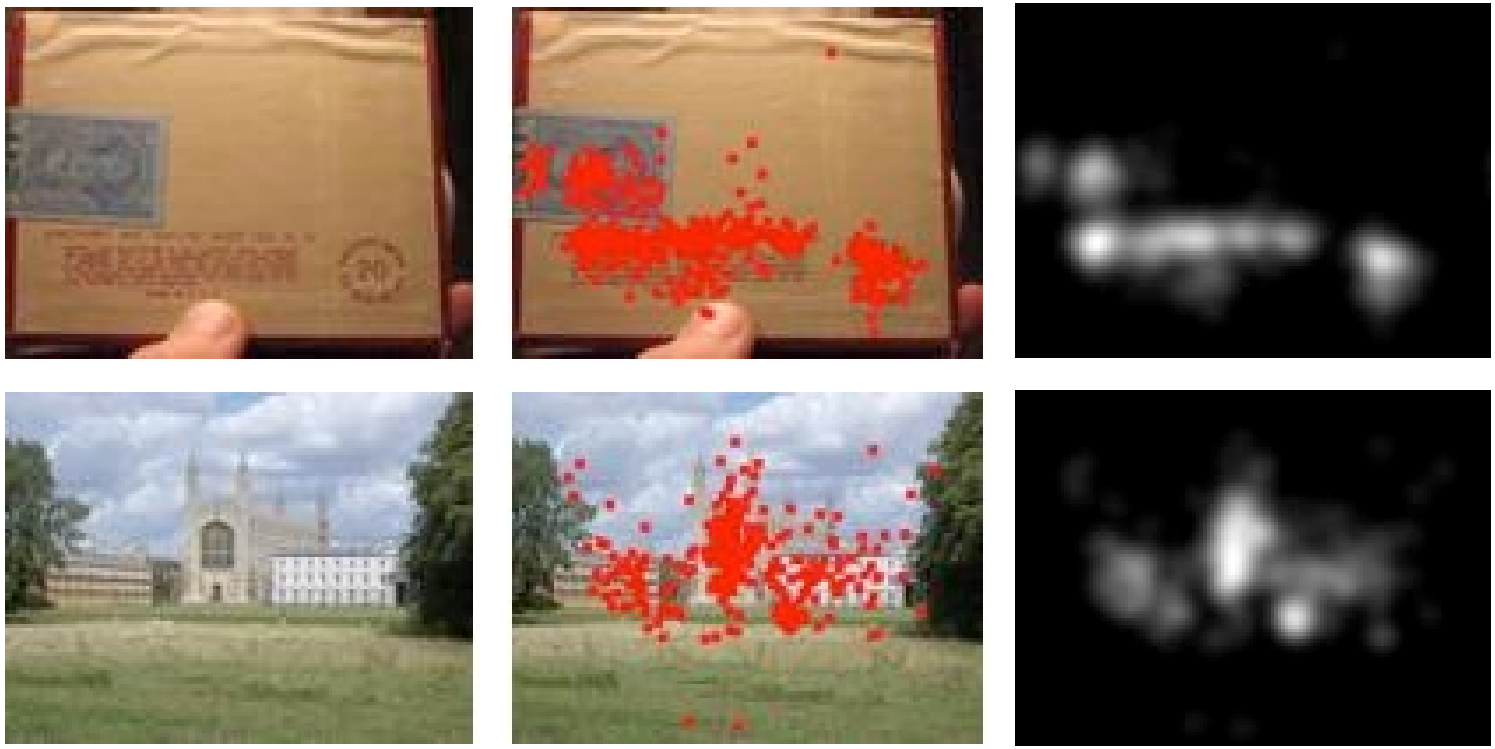
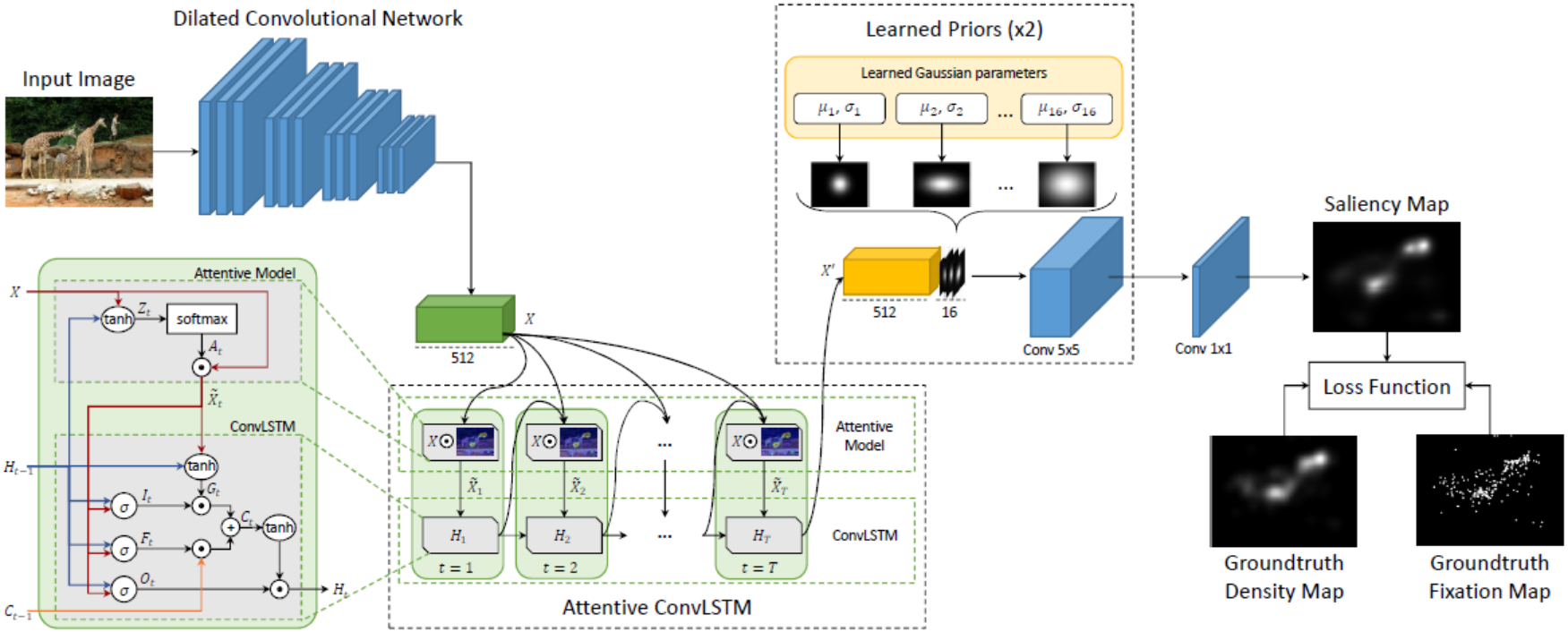
Saliency Prediction



Original Images[1] Eye Fixations[1] Saliency Maps[1]

[1] http://saliency.mit.edu/results_mit300.html

Deep Learning-Based Saliency Predictor



Saliency Attentive Model (SAM)
[Cornia et al. 2018]

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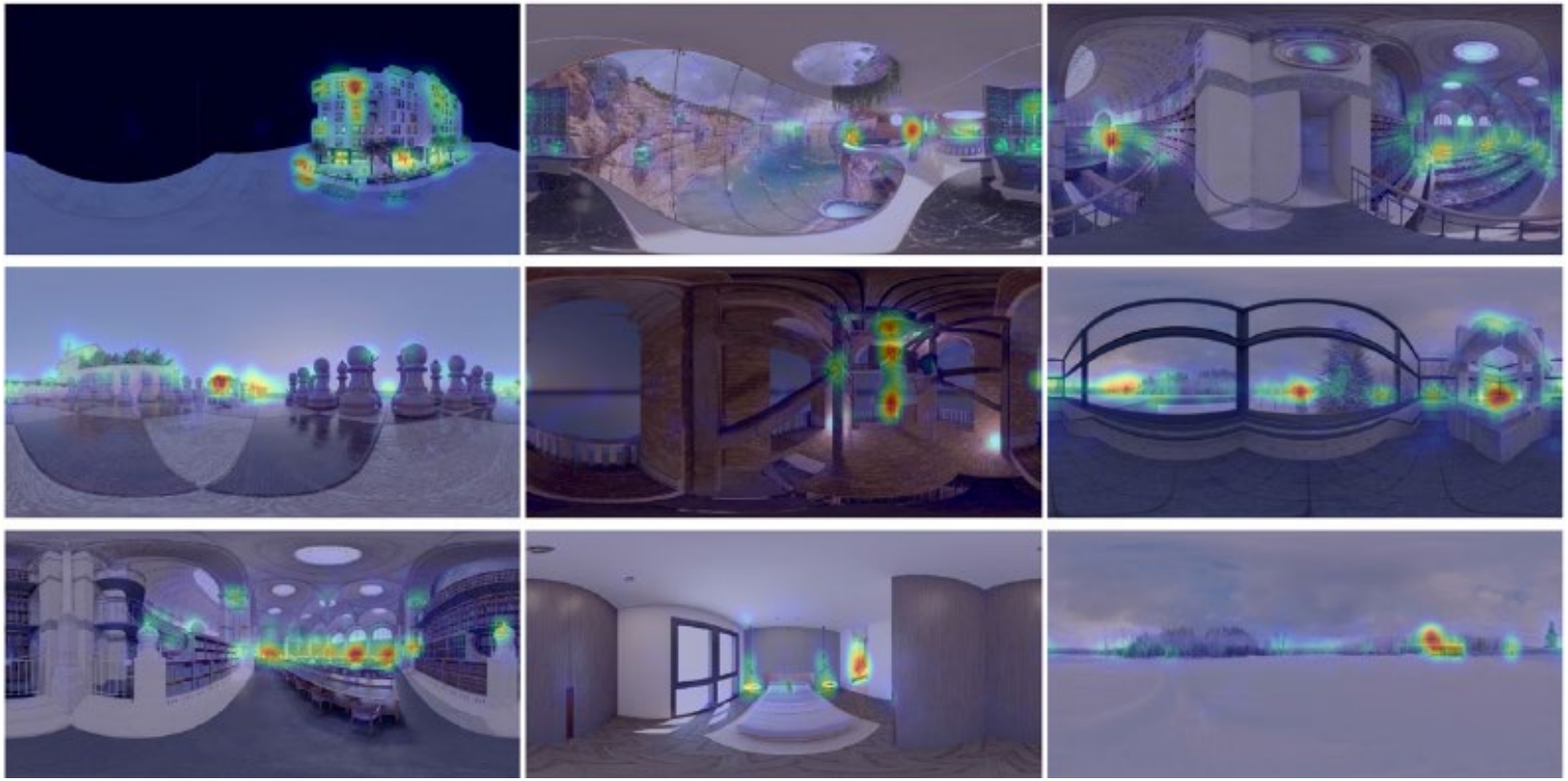
Saliency in 360° Images



Saliency in 360° Images
[Sitzmann et al. 2018]

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Saliency in 360° Videos

Saliency in 360° Videos
[Xu et al. 2018]

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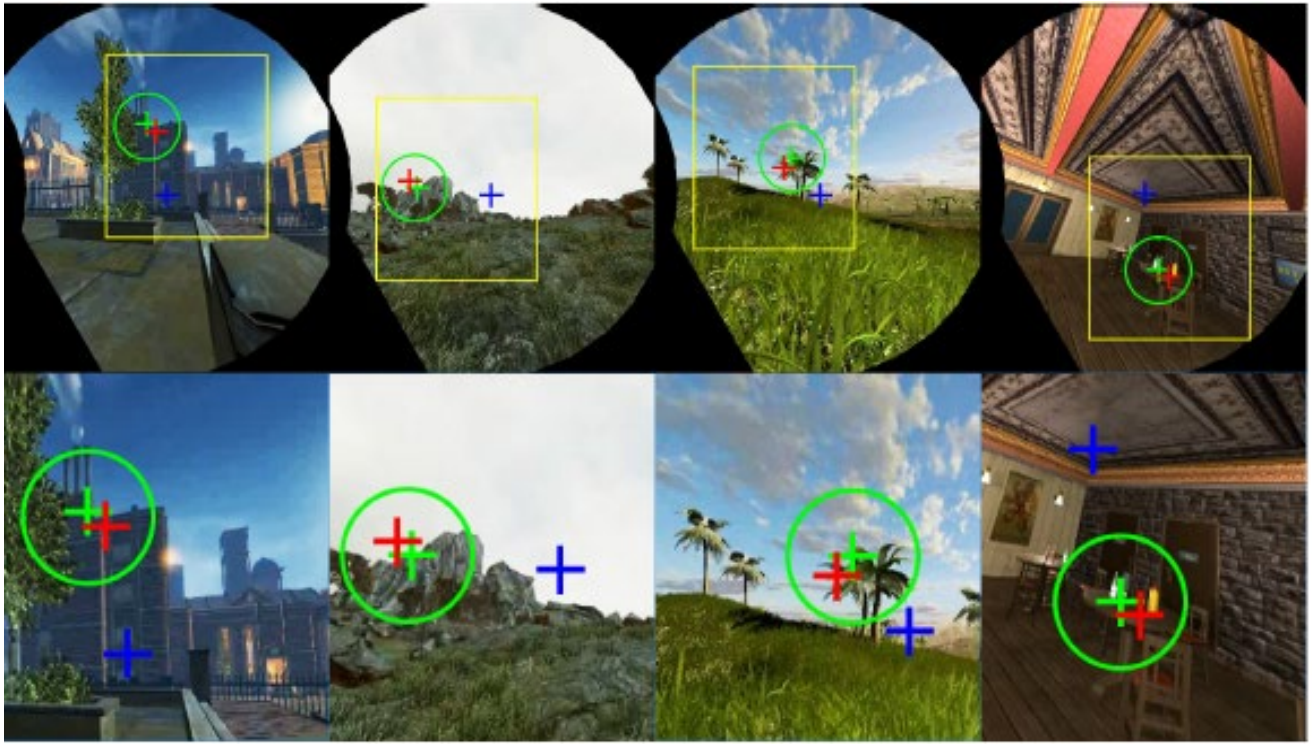
Gaze Prediction in Static Virtual Scenes



Gaze Prediction in Static Virtual Scenes
[Hu et al. 2019]

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Our Work *vs.* Previous Work

- Goal: **2D gaze positions** *vs.* salient objects/saliency maps
- Scene: **3D virtual scenes** *vs.* images/videos
  dynamic scenes *vs.* static scenes

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Contributions

- Propose a novel CNN-based gaze prediction model (DGaze)
- Provide comprehensive analyses of human gaze behaviors in dynamic virtual scenes
- Build an eye tracking dataset that contains 43 users' gaze data in 5 dynamic scenes

Workflow

- Data Collection
- Gaze Behavior Analysis
- CNN-Based Gaze Prediction Model (DGaze)
- Model Evaluation

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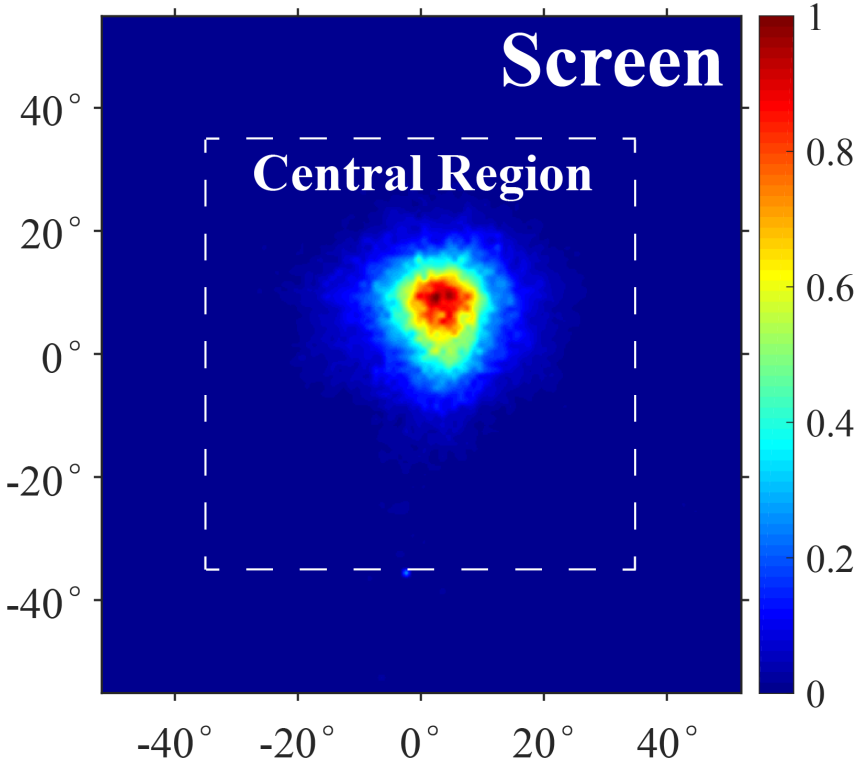
Data Collection

- Participants: 43 users (25 male, 18 female, ages 18-32)
- Stimuli: 5 dynamic virtual scenes
- System: HTC Vive + eye tracker
- Procedure: free-viewing, no task
- Data: scene screenshots + gaze positions + head poses + dynamic object positions

Stimuli

Gaze Behavior Analysis: Gaze Analysis

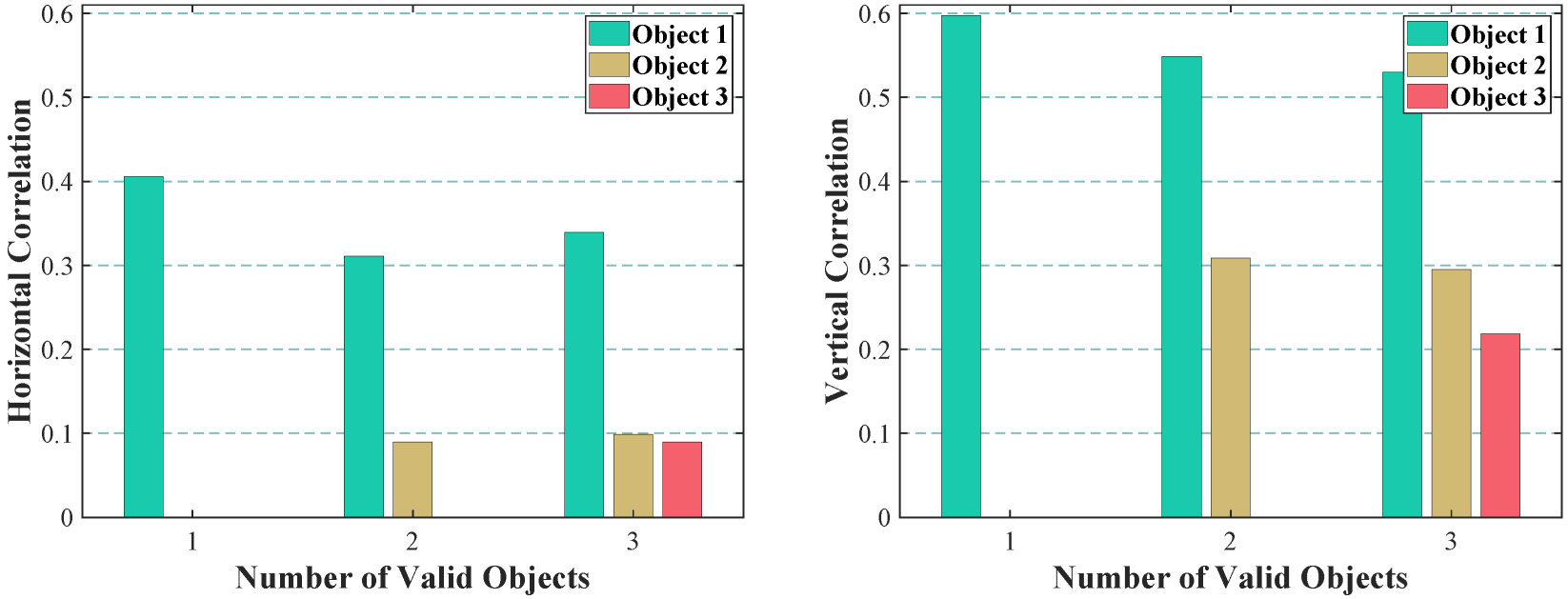


The distribution of users' gaze positions on the HMD's screen

Most of the gaze data lies in the central region of the screen.

Gaze Behavior Analysis: Gaze-Object Analysis

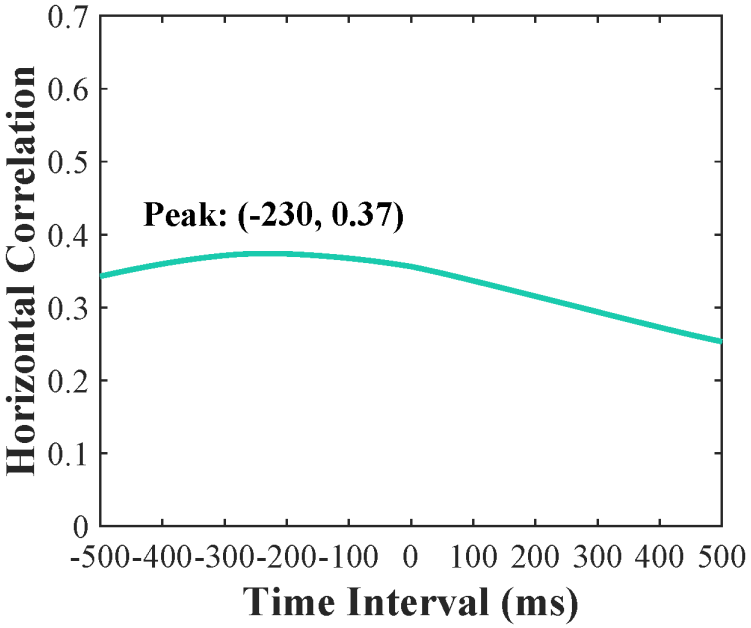
Spearman's rank correlation coefficient

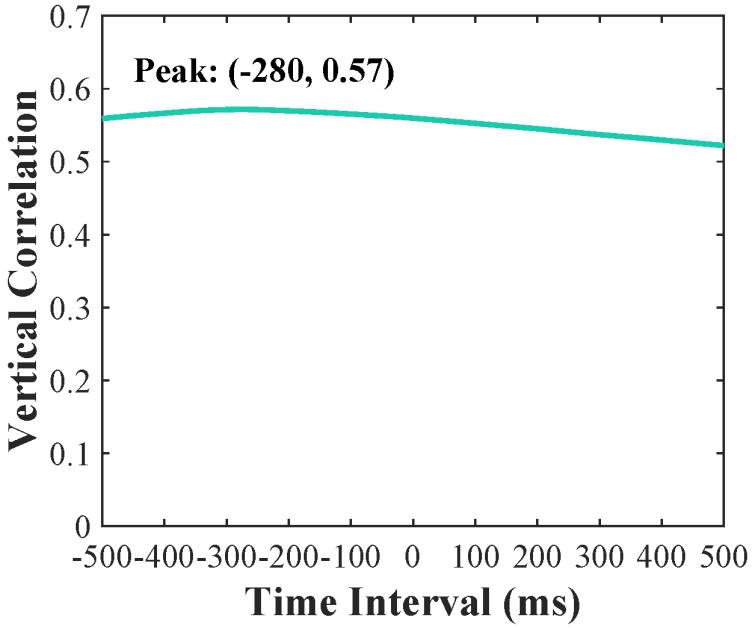


The horizontal (left) and vertical (right) correlations between gaze positions and object positions

Users' gaze positions are strongly correlated with dynamic object positions.

Gaze Behavior Analysis: Gaze-Object Analysis

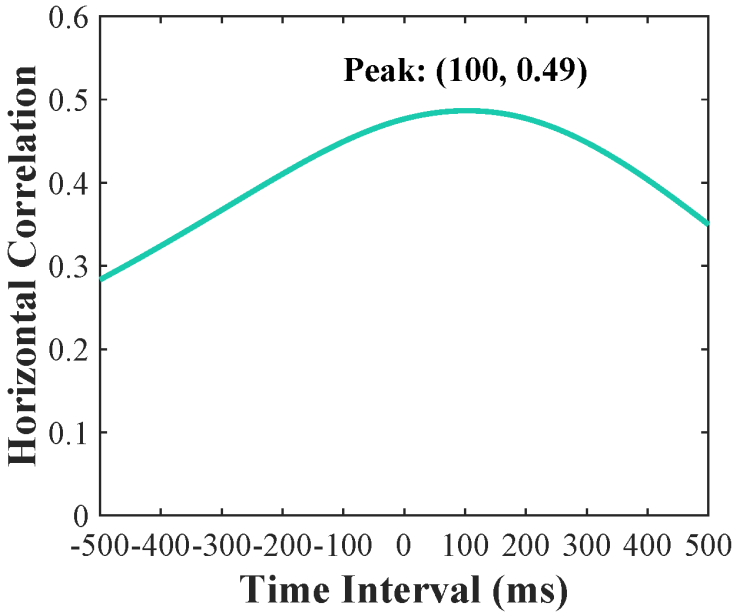


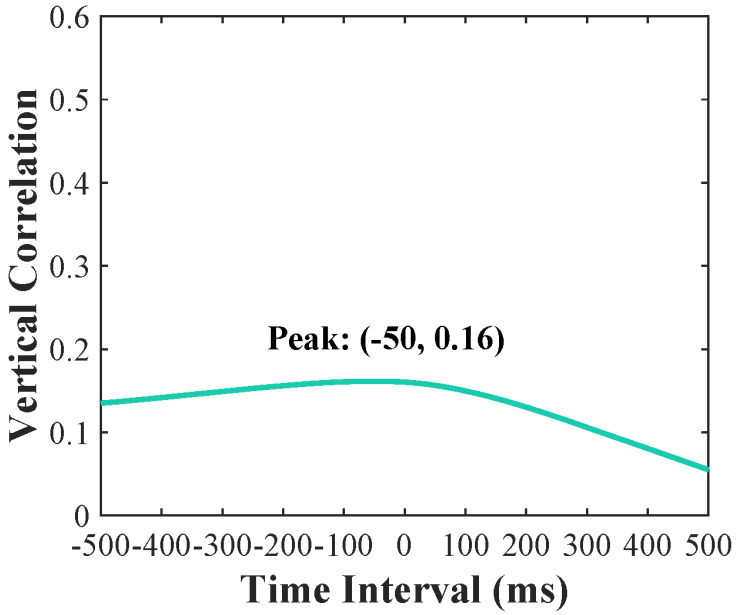


The correlations between gaze positions and the nearest object positions at different time intervals

Both realtime and past object positions are correlated with gaze positions.

Gaze Behavior Analysis: Gaze-Head Analysis





The correlations between gaze positions and head velocities at different time intervals

Both realtime and past head velocities are correlated with gaze positions.

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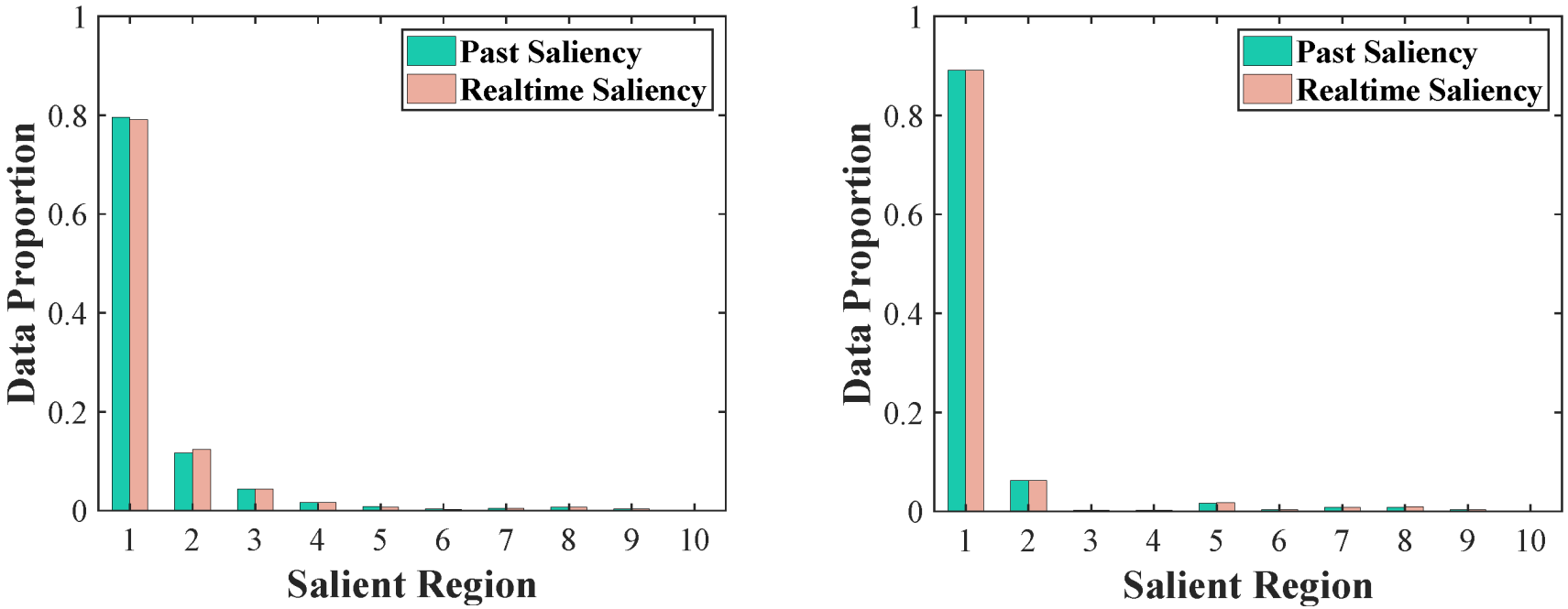
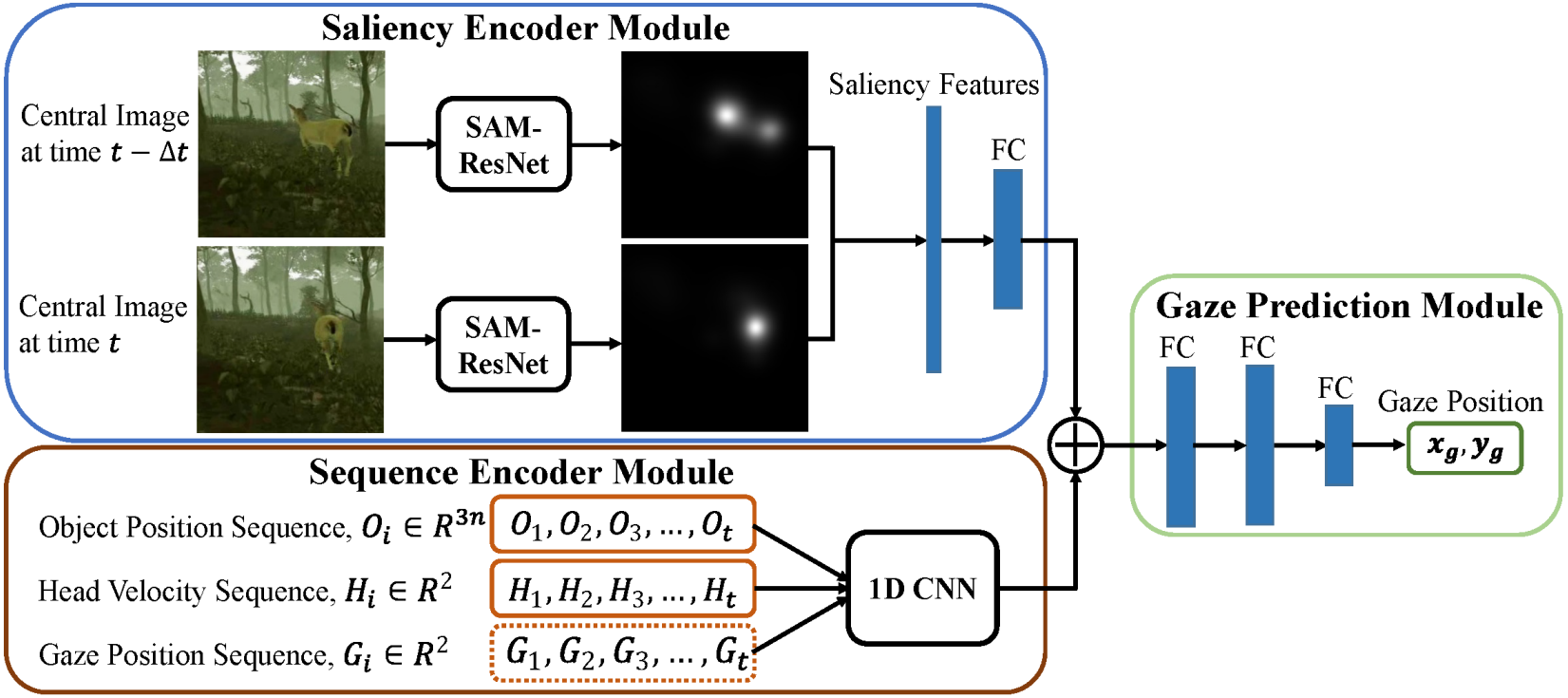
Gaze Behavior Analysis: Gaze-Saliency Analysis



The distributions of gaze positions on salient regions of the whole image (left) and the central image (right)

Most of the gaze positions lie in the most salient region (region 1).

CNN-Based Gaze Prediction Model (DGaze)



Architecture of DGaze model

DGaze_ET: predict future gaze positions with higher precision by combining accurate past gaze data.

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Model Evaluation: Realtime Prediction

		DGaze	SGaze	Mean	Center	Object
Dynamic	Mean	7.11°	9.11°	10.04°	12.46°	13.25°
	SEM	0.01°	0.01°	0.01°	0.01°	0.02°
Static	Mean	7.71°	8.52°	10.93°	11.16°	
	SEM	0.01°	0.01°	0.01°	0.01°	

DGaze and other methods' realtime prediction performances on the dynamic dataset and the static dataset

DGaze performs best in both dynamic and static scenes.

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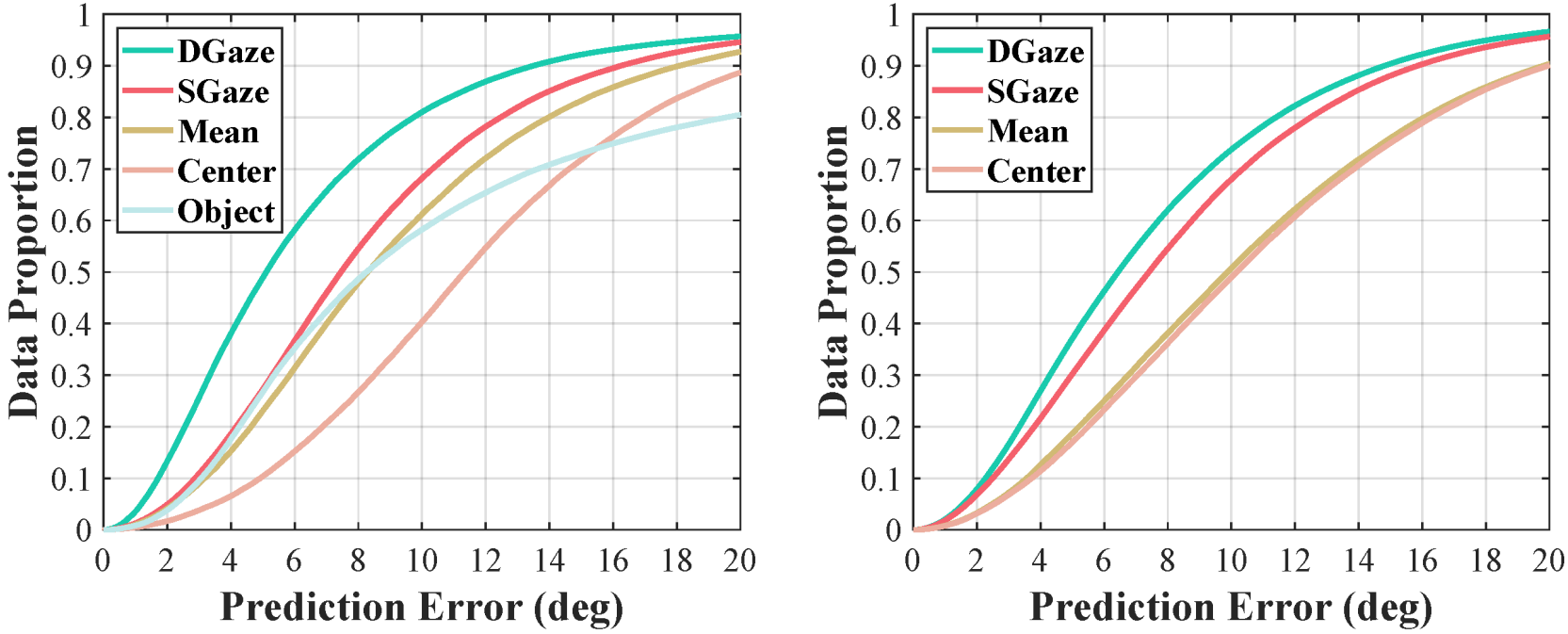
Model Evaluation: Realtime Prediction



Cumulative distribution function (CDF) of the prediction errors on the dynamic dataset (left) and the static dataset (right)

DGaze performs best in terms of CDF curve.

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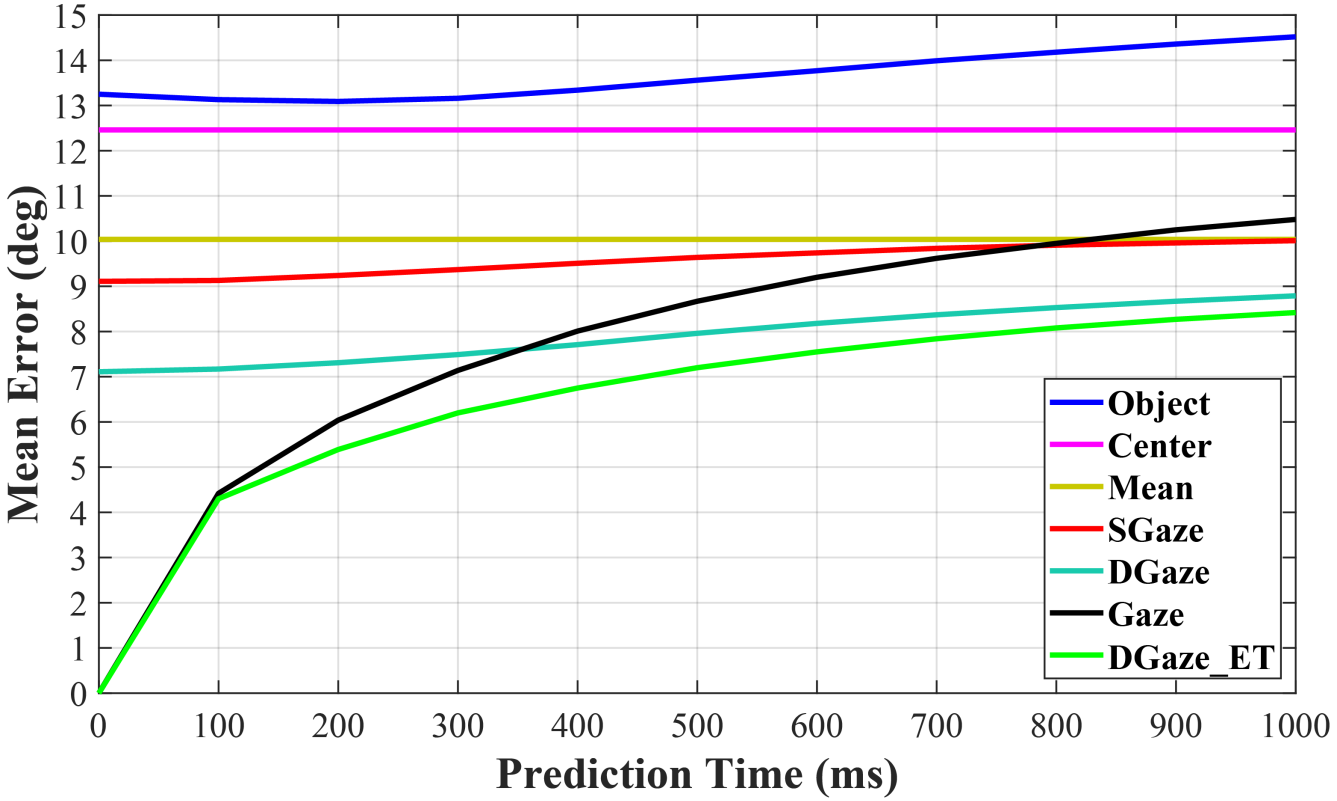
Model Evaluation: Future Prediction



DGaze and other methods' future prediction performances in dynamic scenes

DGaze and DGaze_ET outperform other methods in different prediction times.

Gaze-Contingent Rendering

Gaze-Contingent Rendering

User Study

DGaze *vs.* prior method

t-test, $p < 0.01$

DGaze performs significantly better than prior method.

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Task-Oriented Game

Game Scene

Limitations

- Our dataset is restricted to free-viewing conditions
- We only utilize moving animals as our dynamic objects in the data collection process
- The influence of sound is not considered in our model

Future Work

- Overcome the limitations
- Improve our model's performance by fine-tuning the parameters
- Extend our model to consider more input features
- Convert our model to other systems like AR and MR systems

Thank you!