Gaze Analysis and Prediction in Virtual Reality

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Outline

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- Background
- Related Work
- SGaze: A Data-Driven Eye-Head Coordination Model for Realtime Gaze Prediction (TVCG 2019)
- DGaze: CNN-Based Gaze Prediction in Dynamic Scenes (TVCG 2020)
- Conclusion and Discussion

Eye Tracking Technology

Eye Tracking Technology[1]

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

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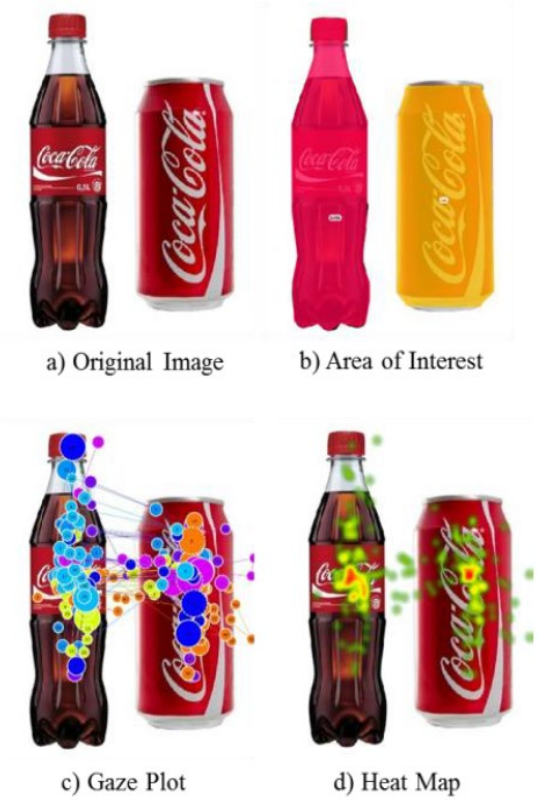
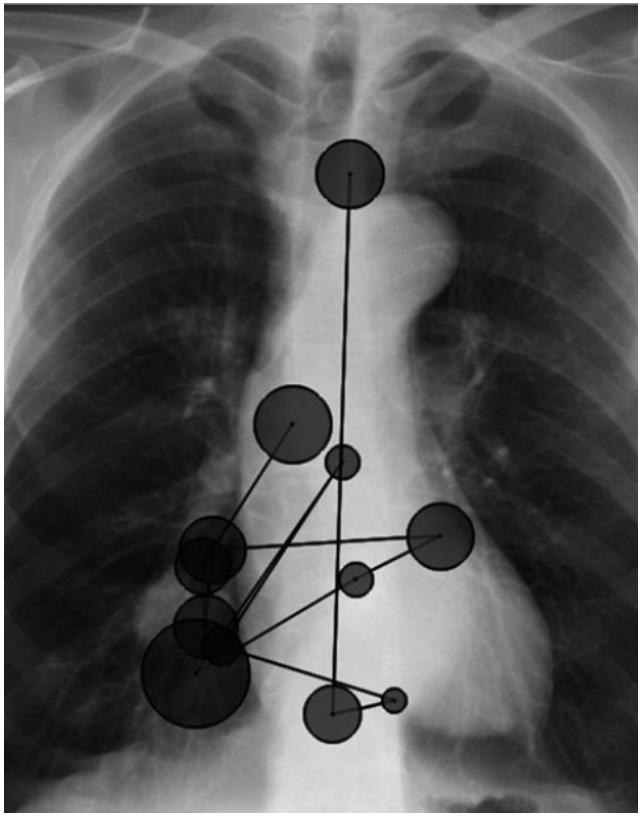
Eye Tracking Technology





Marketing Strategy Analysis
[Zamani et al. 2016]

Cognitive Research
[Kiefer et al. 2017]

Medical Education
[Kok et al. 2017]

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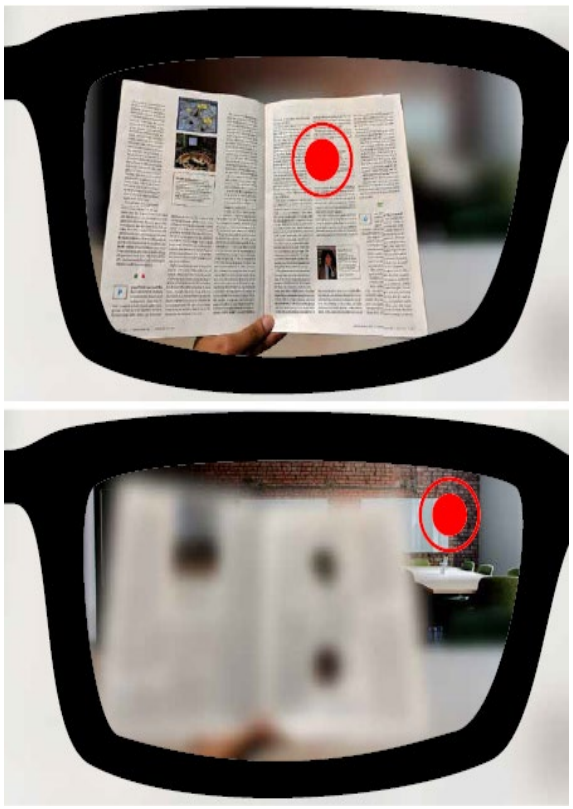
Eye Tracking Technology

Gaze-based Interaction
[Pfeiffer et al. 2008]

Collaborative System
[Zhang et al. 2017]



Gaze-contingent Eyeglasses
[Padmanaban et al. 2019]

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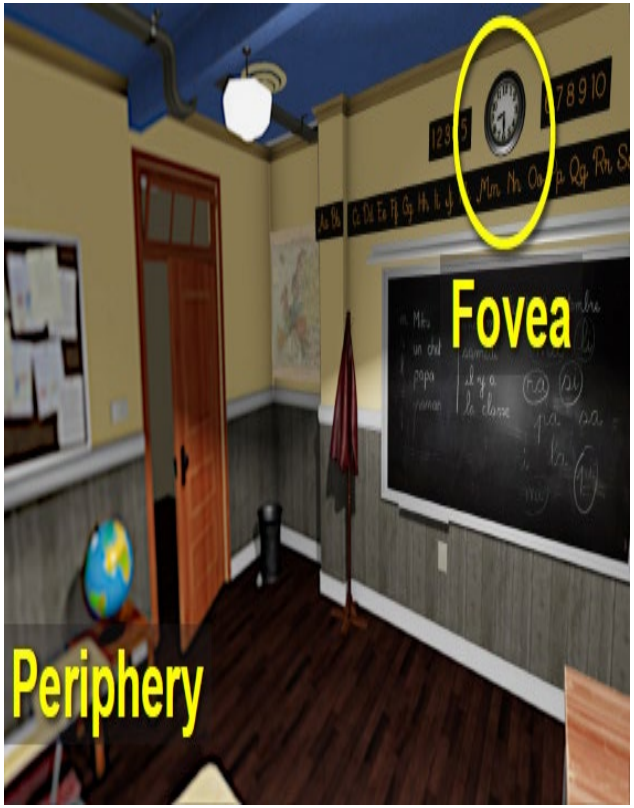
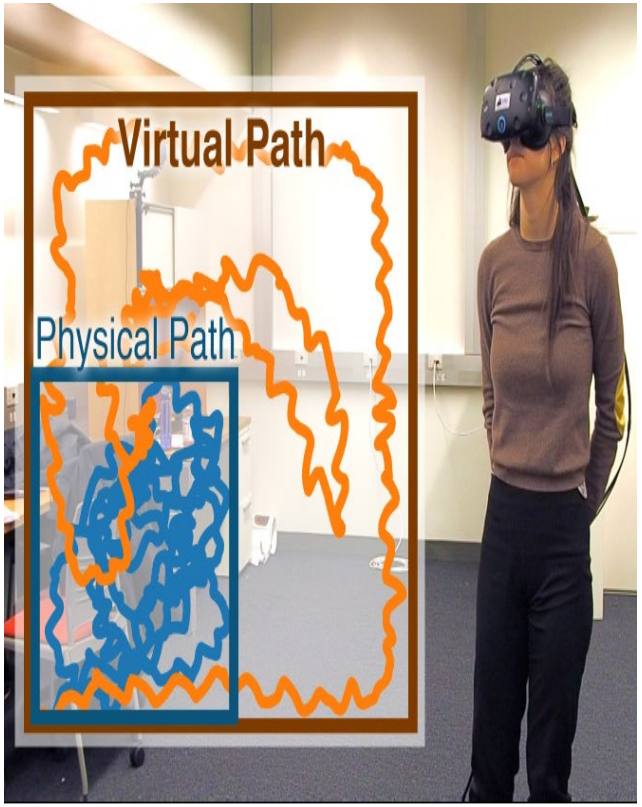
Eye Tracking in Virtual Reality



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

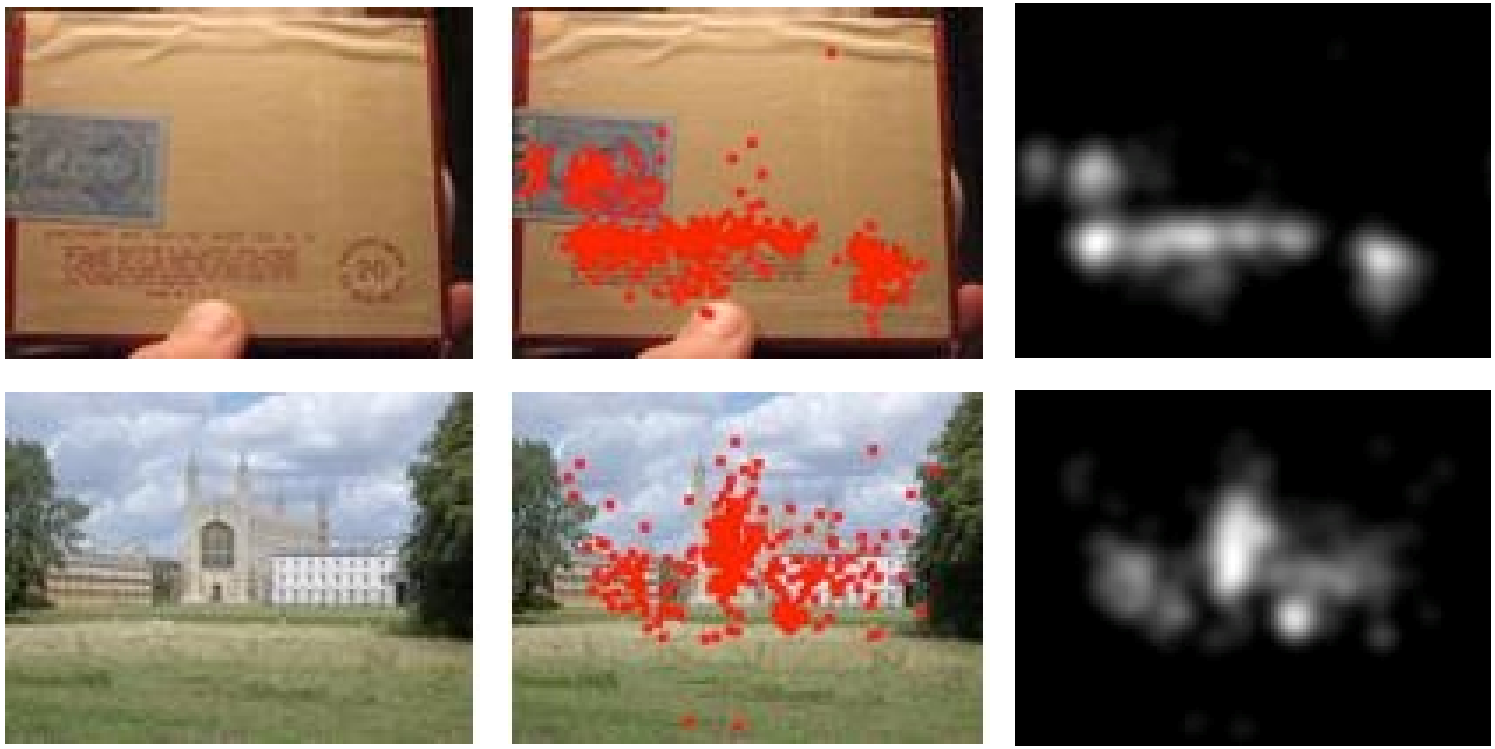
- Analyze users' gaze behaviors in virtual reality
- Predict users' gaze positions based on the characteristics of users' gaze

Salient Object Detection

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

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

Saliency Prediction



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

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

Our Work *vs.* Previous Work

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

SGaze: A Data-Driven Eye-Head Coordination Model for Realtime Gaze Prediction

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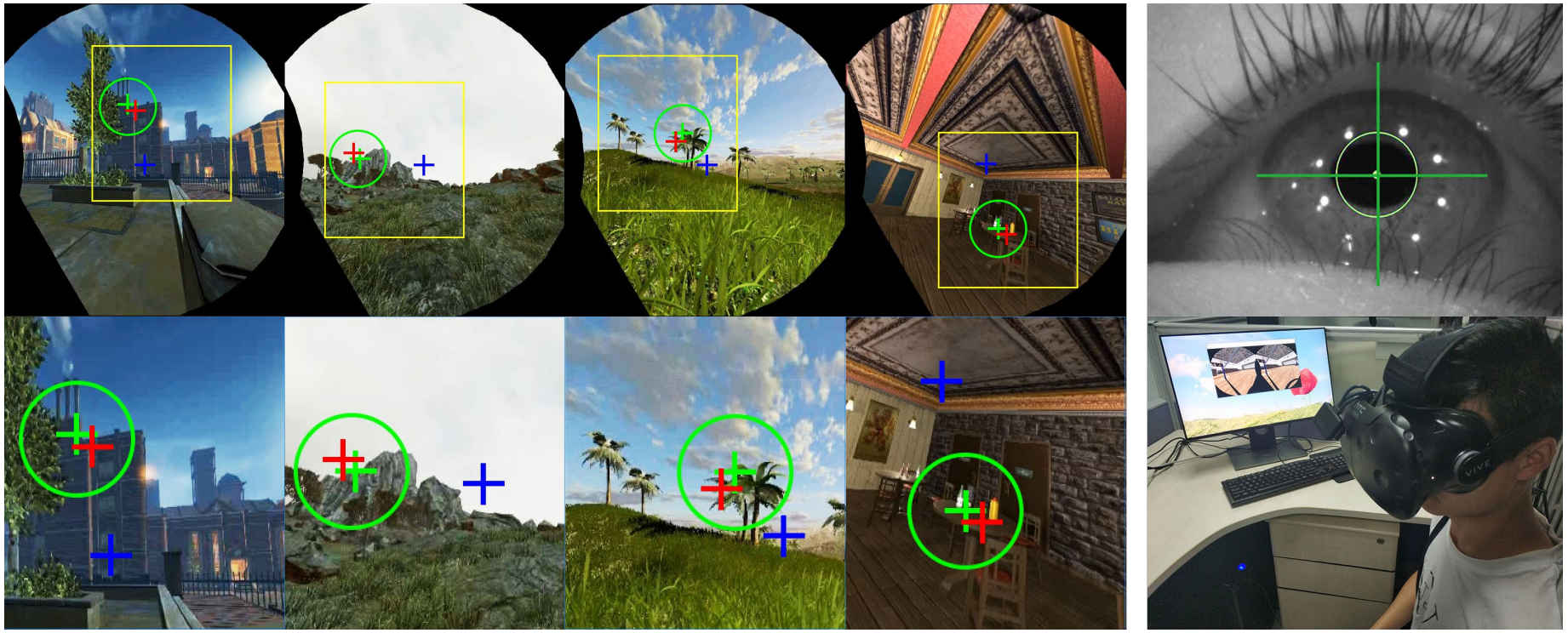


SGaze

Eye-Head Coordination Model (SGaze)

$$\boldsymbol{x_g(t) = \alpha_x \cdot v_{hx}(t + \Delta t_{x1}) + \beta_x \cdot a_{hx}(t) + F_x(t + \Delta t_{x2}) + G_x(t) + H_x(t)}$$
$$\boldsymbol{y_g(t) = \alpha_y \cdot v_{hy}(t + \Delta t_{y1}) + F_y(t + \Delta t_{y2}) + G_y(t) + H_y(t)}$$

x_g, y_g: gaze position

v_{hx}, v_{hy}, a_{hx} : head velocity and acceleration

F_x, F_y: content

G_x, G_y: task

H_x, H_y: other factors

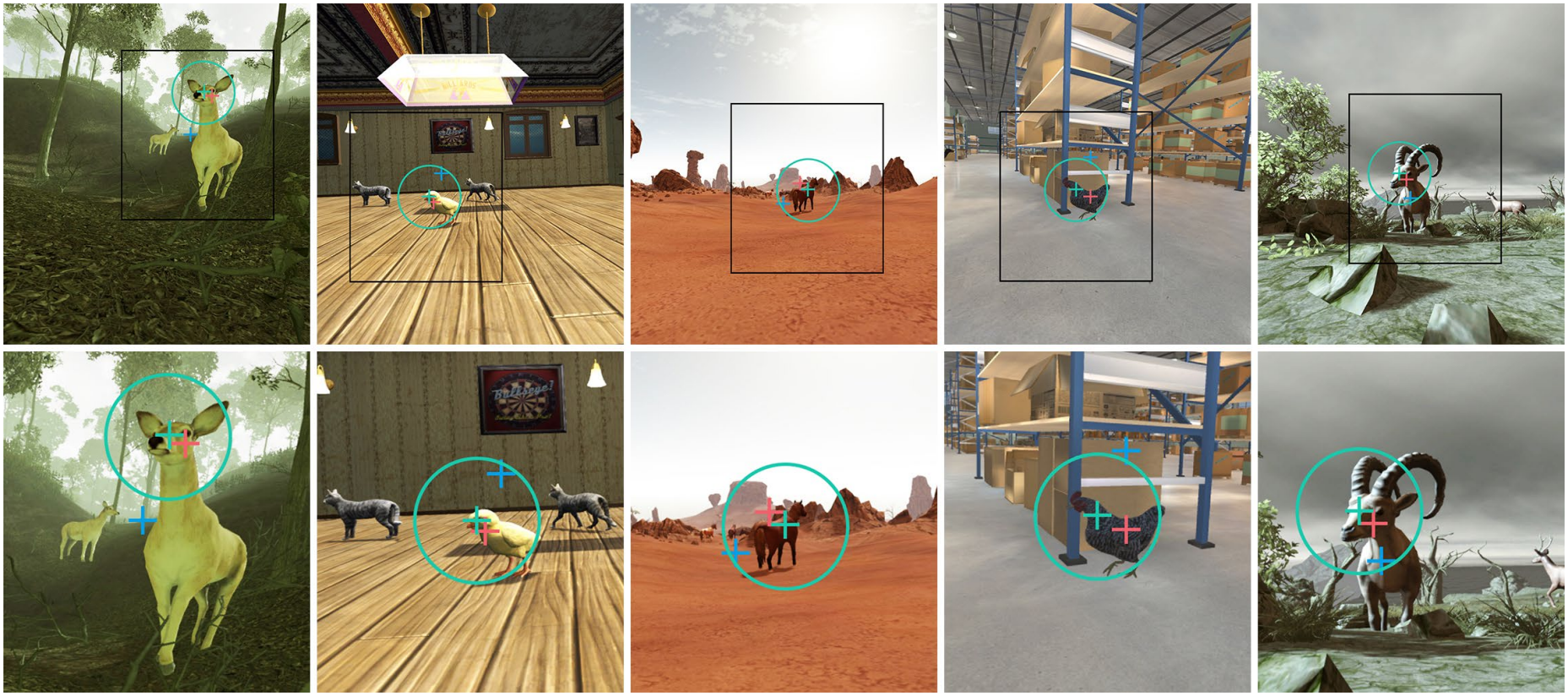
α_x, α_y, β_x: the linear influence of velocity and acceleration

Δt_{x1}, Δt_{y1}: eye-head latencies

Eye-Head Linear Correlation

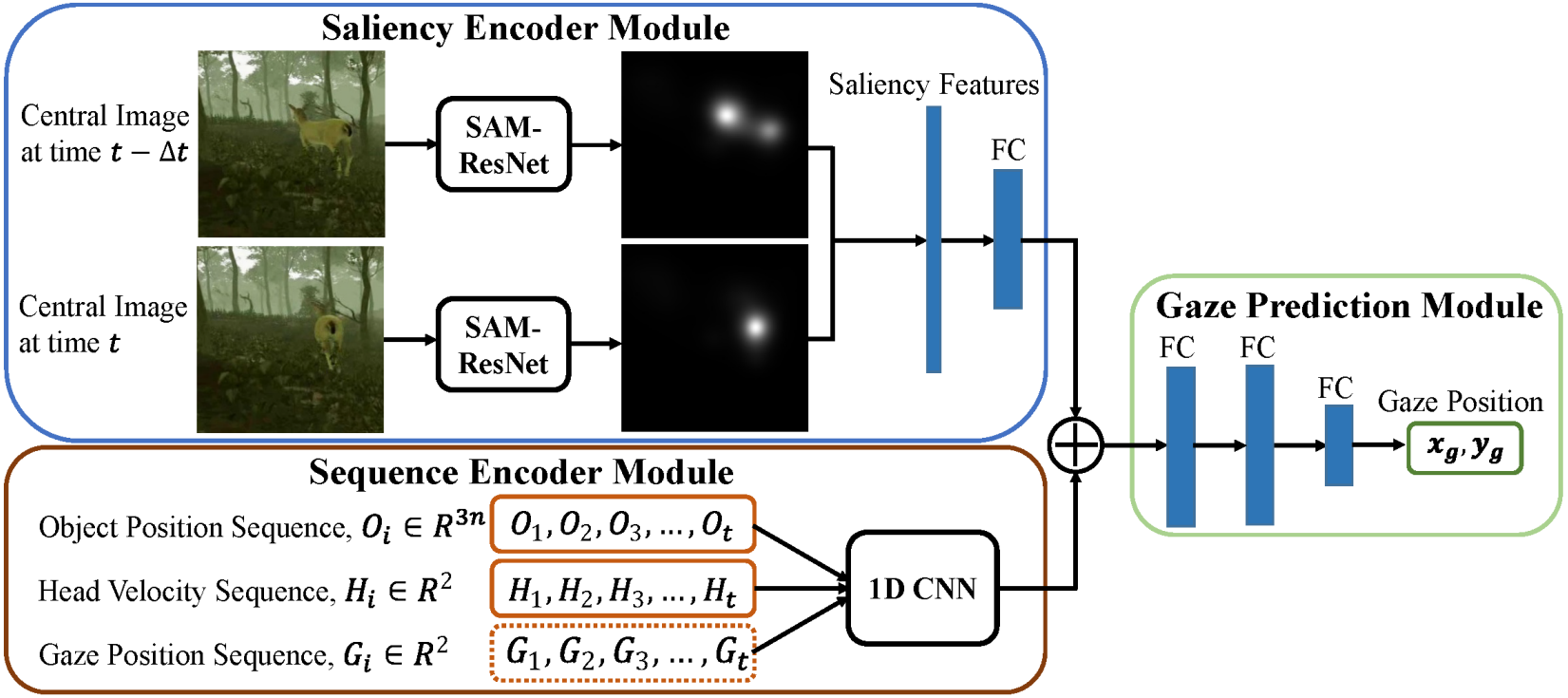
Eye-Head Latency

DGaze: CNN-Based Gaze Prediction in Dynamic Scenes



DGaze

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.

Conclusion

- An eye-head coordination gaze prediction model

Predict realtime gaze positions in static virtual scenes

- A CNN-based gaze prediction model

Predict realtime and future gaze positions in dynamic virtual scenes

Discussion

- What kind of VR task-oriented conditions deserve to be studied?
  VR games, 3D user interfaces, or other tasks?

- What factors may influence users' gaze behaviors in VR?
  Sound, body and hand gesture, behavior habit, or other factors?

- Potential application of eye tracking technology in VR.