PUI Perceptual User Interfaces

cbb Computational Biophysics and Biorobotics

SimTech

University of Stuttgart Germany

Towards Human-centred Artificial Intelligence

Research Talk

Zhiming Hu

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Perceptual User Interfaces Group, University of Stuttgart

Computational Biophysics and Biorobotics Group, University of Stuttgart

Stuttgart Center for Simulation Science (SimTech)

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Education Background & Academic Positions

Education Background

- Ph.D. in Computer Software and Theory 2017.09-2022.07
  Peking University, Supervised by Prof. Guoping Wang

- B.Eng. in Optical Engineering 2013.09-2017.07
  Beijing Institute of Technology

Academic Positions

- Post-doctoral Researcher 2022.08-now
  University of Stuttgart, Led by Prof. Andreas Bulling & Prof. Syn Schmitt

Awards & Honours

As a researcher:

- Best Doctoral Student Paper Award Nominees at INTERACT 2023
- **TVCG Best Journal Award Nominees at IEEE VR 2021** (top 2%, first time for Chinese researchers)

As a student:

- **National Scholarship** (top 2%), 2021
- CSC (China Scholarship Council) Scholarship, 2020
- Chancellor's Scholarship (top 2%), 2020
- Leo KoGuan Scholarship (top 5%), 2019
- **Leader Scholarship** (top 0.2%, 7 out of over 3800 students), 2017
- **National Scholarship** (top 2%), 2016
- **National Scholarship** (top 2%), 2014

Professional Activities

Reviewing

- Journals: IMWUT, TiiS, T-MM, TVCG, IJHCI, MTAP
- Conferences: SIGGRAPH Asia, CVPR, ICCV, ECCV, CHI, UIST, IEEE VR, ISMAR

Organising committee

- Virtualisation Chair for ETRA 2024
- Associate Chair for MuC 2023
- Technical Program Committee member for iWOAR 2023

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Research Interests

- Human-computer interaction
- Virtual reality
- Eye tracking
- Human-centred artificial intelligence

Research goal

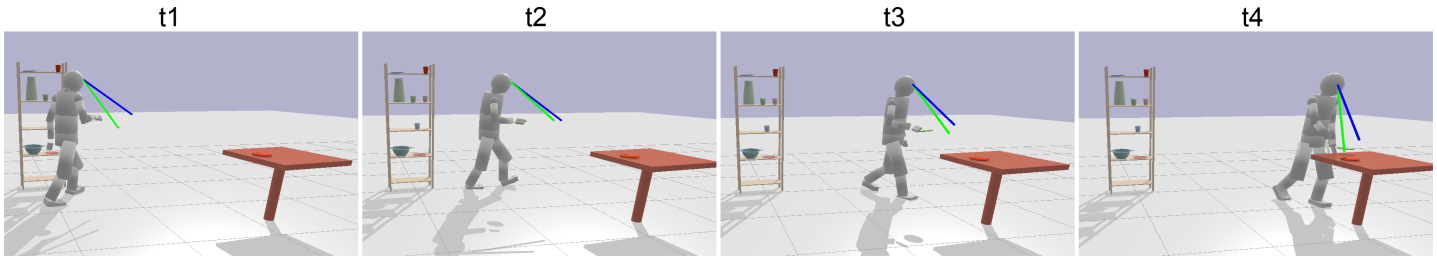
Develop human-aware intelligent user interfaces that can accurately model human daily behaviours

Towards Human-aware Intelligent User Interfaces

- Human behaviour estimation and prediction
  How to acquire human behaviour data?
- Computational human activity analysis
  What can we learn from human data?
- Human-aware intelligent system
  How to enhance the system's intelligence using human data?

Towards Human-aware Intelligent User Interfaces

- Human behaviour estimation and prediction
- Computational human activity analysis
- Human-aware intelligent system



Human daily pick and place actions

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Human Behaviour Estimation and Prediction

- Head pose-based gaze estimation
- Task-oriented gaze prediction
- Privacy-preserving gaze estimation
- Gaze super-resolution

Problem definition

- Input: head pose + scene content
- Output: gaze position

Static virtual environments [Hu TVCG'19]

SGaze: An Eye-head Coordination Model for Gaze Prediction

$$\tilde{x}_g = \alpha_x \cdot \tilde{v}_{hx}(t + \Delta t_x) + \beta_x \cdot a_{hx} + b_x \cdot x_S + c_x$$
$$\tilde{y}_g = \alpha_y \cdot \tilde{v}_{hy}(t + \Delta t_y) + b_y \cdot y_S + c_y$$

$\tilde{x}_g$, $\tilde{y}_g$: predicted eye gaze
$\tilde{v}_{hx}$, $\tilde{v}_{hy}$: head velocity
Δt_x, Δt_y: time interval between gaze and head
a_{hx}: horizontal head acceleration
x_S, y_S: salient positions
α_x, α_y, β_x, b_x, b_y, c_x, c_y: learned parameters

[Hu TVCG'19]

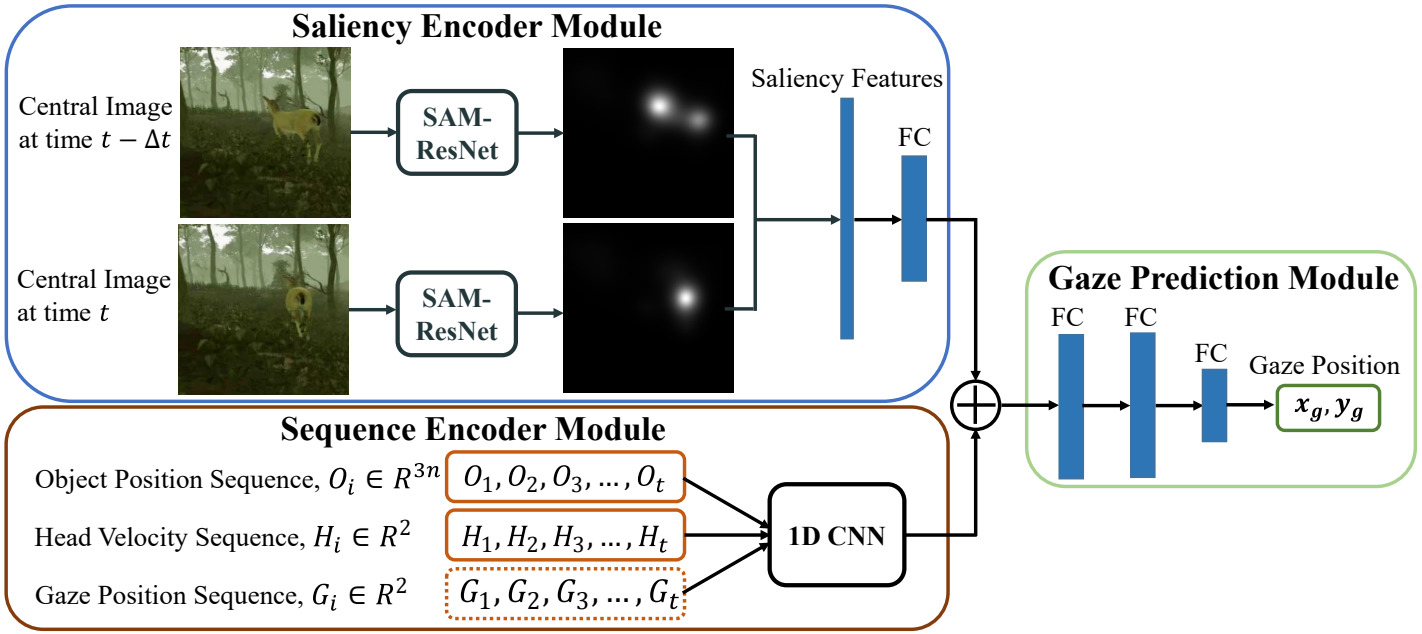
Problem definition

- Input: head pose + scene content + dynamic objects
- Output: gaze position

Dynamic virtual environments [Hu TVCG'20]

DGaze: CNN-based Gaze Prediction in Dynamic Scenes

- Gaze estimation using VR content, and head movements
- Gaze forecasting using past gaze positions



[Hu TVCG'20]

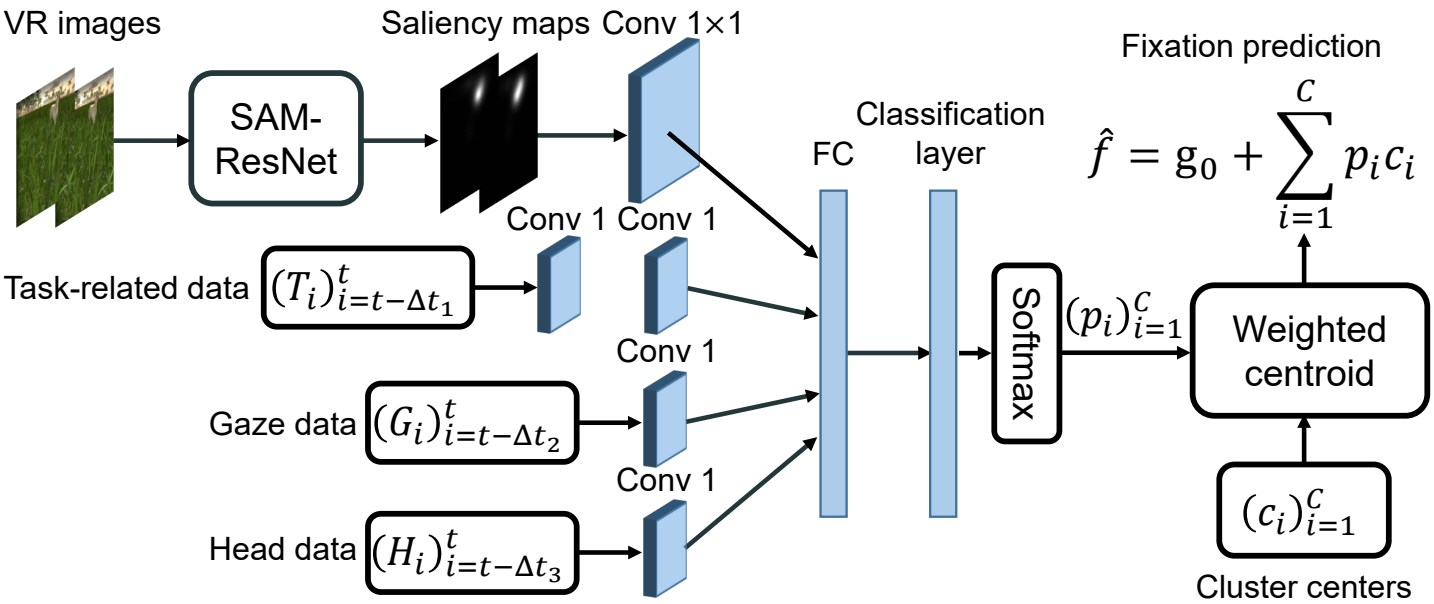
Problem definition

- Input: head pose + scene content + task-related information
- Output: future gaze fixation

Task-oriented virtual environments [Hu TVCG'21]

FixationNet: Gaze Forecasting in Task-oriented Environments

- Extract features from VR content, past gaze and head data
- Forecast fixation using prior knowledge of gaze distribution



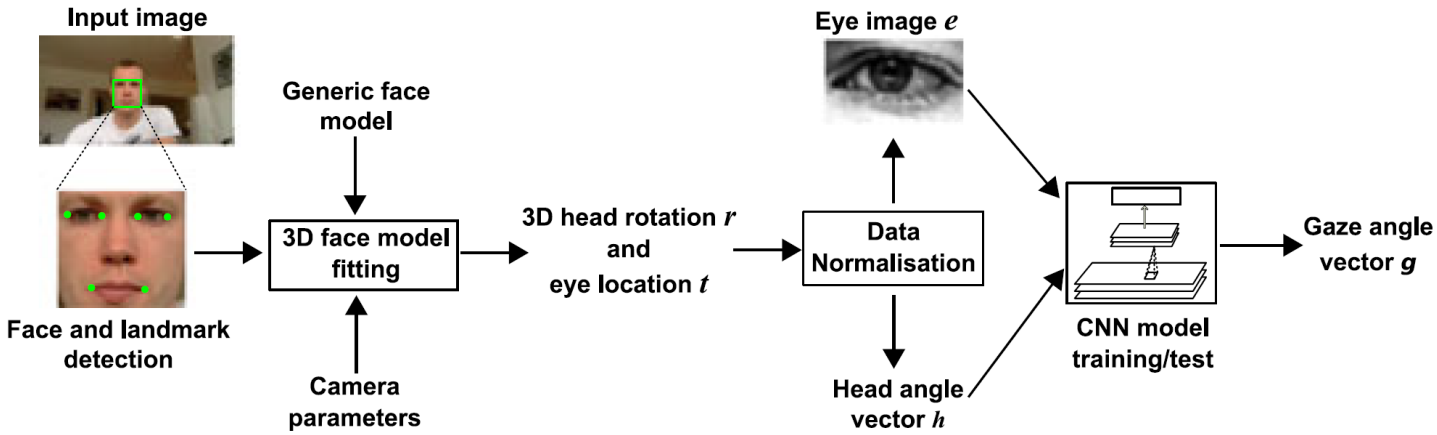
[Hu TVCG'21 **Best Journal Nominees Award**]

Background

- Gaze estimation from face or eye images
- Face or eye images are privacy-sensitive

Problem definition

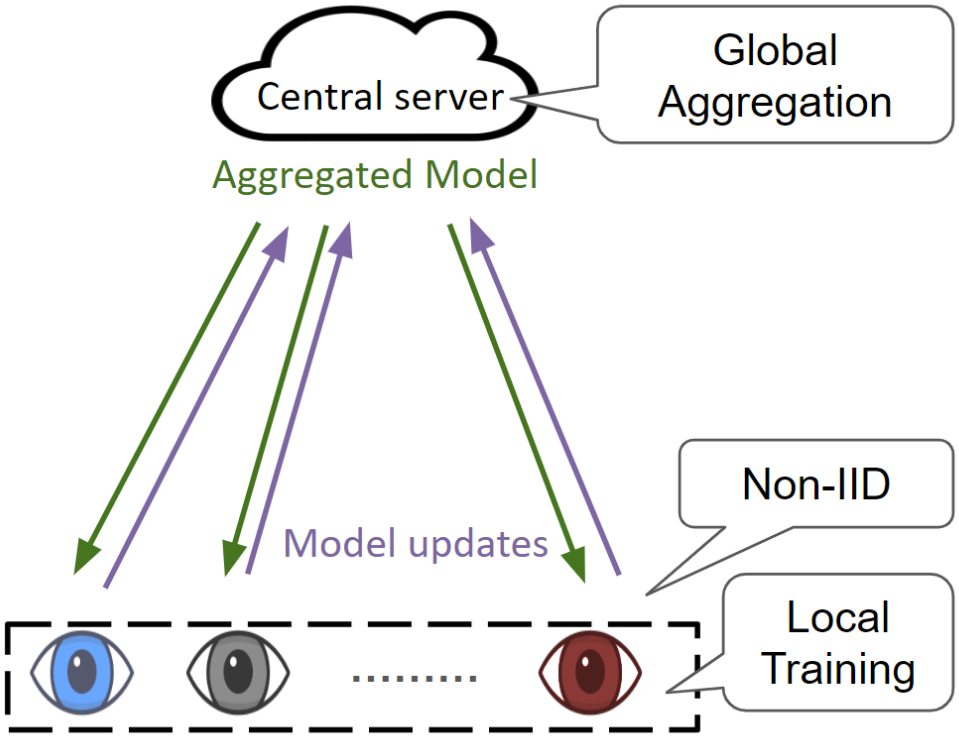
- Enhance the privacy of appearance-based gaze estimators



Appearance-based gaze estimation [Zhang PAMI'17]

Privacy-preserving Gaze Estimation using Federated Learning

- Local training to preserve privacy
- Global aggregation to ensure accuracy



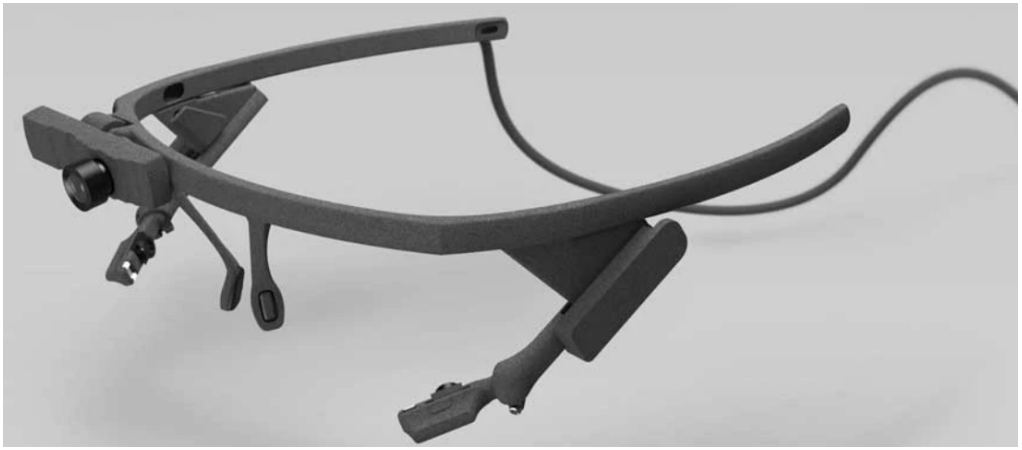
Gaze Super-resolution

Background

- Mobile eye trackers usually suffer from low-resolution
- High-resolution gaze data is significant for many applications

Problem definition

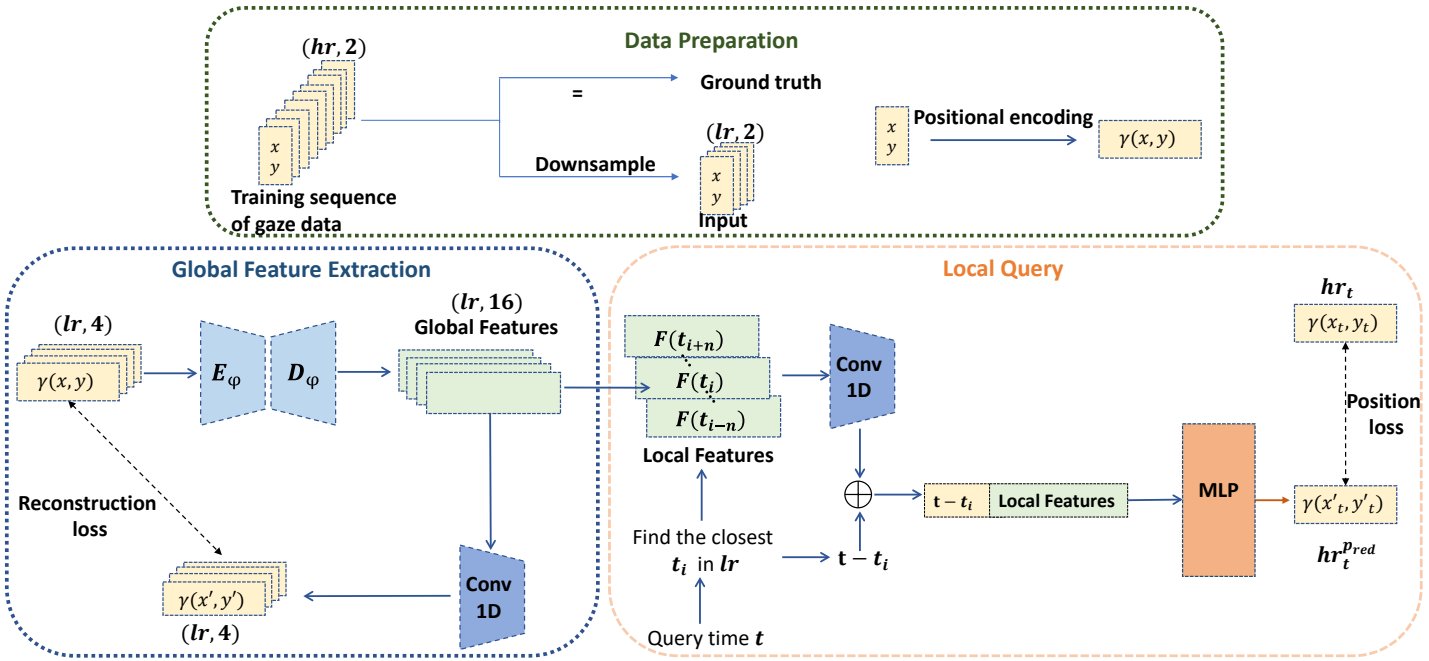
- Input: low(er)-resolution gaze data
- Output: high(er)-resolution gaze data



Mobile eye tracker [https://pupil-labs.com/products/core]

SUPREYES: SUPer Resolution for EYES

- Implicit neural representation learning
- Global feature extraction and local query



[Jiao UIST'23]

Summary

- Head pose-based gaze estimation
- Task-oriented gaze prediction
- Privacy-preserving gaze estimation
- Gaze super-resolution

Future work

- Human pose estimation
- Human motion prediction
- Hand pose estimation

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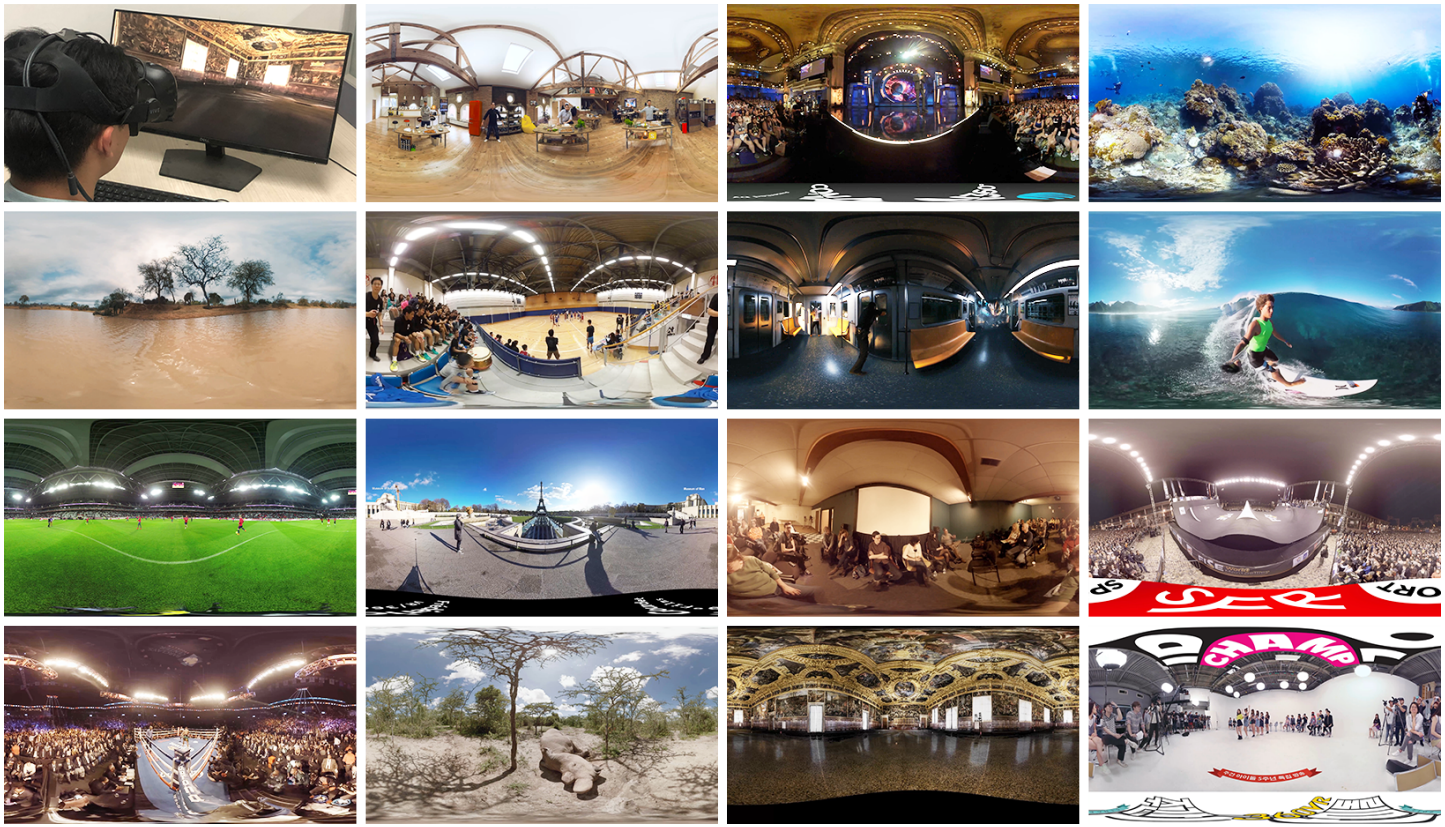
Computational Human Activity Analysis

- Eye and head movement analysis
- Mouse and keyboard behaviour analysis

Problem definition

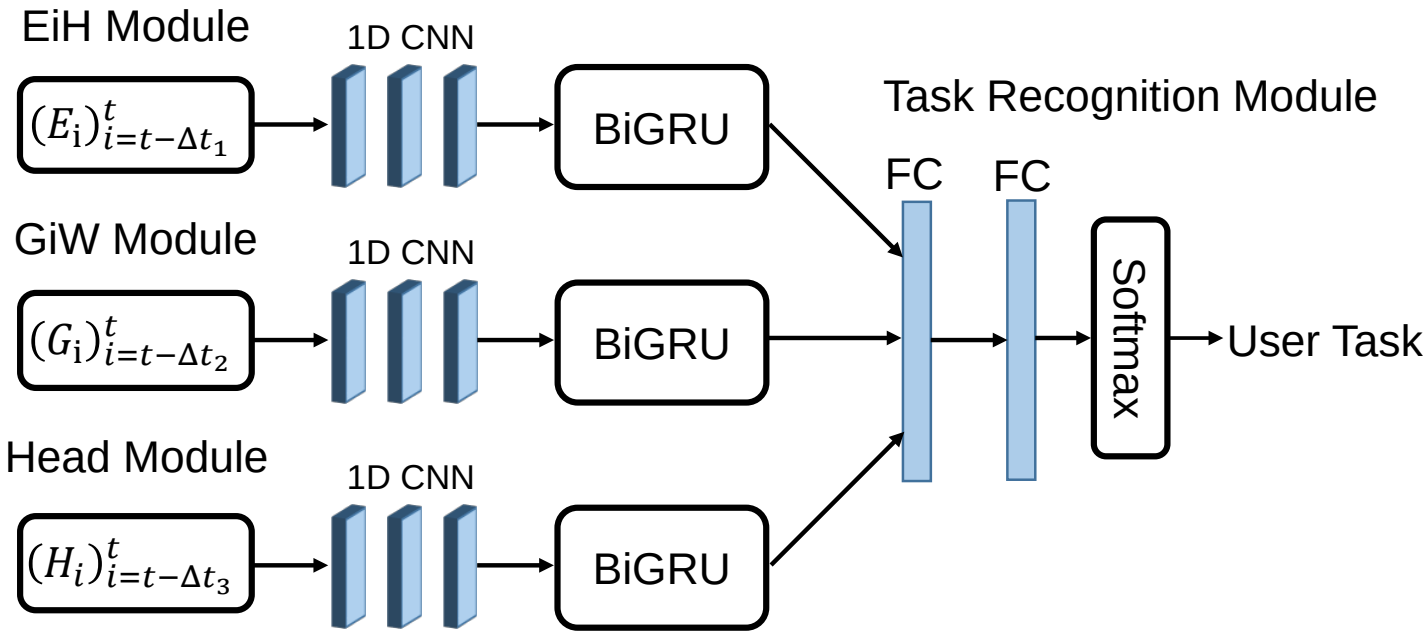
- Analyse eye and head movements under different tasks
- Recognise user tasks from eye and head features



360-degree VR videos [Hu TVCG'22]

EHTask: Task Recognition from Eye and Head Movements

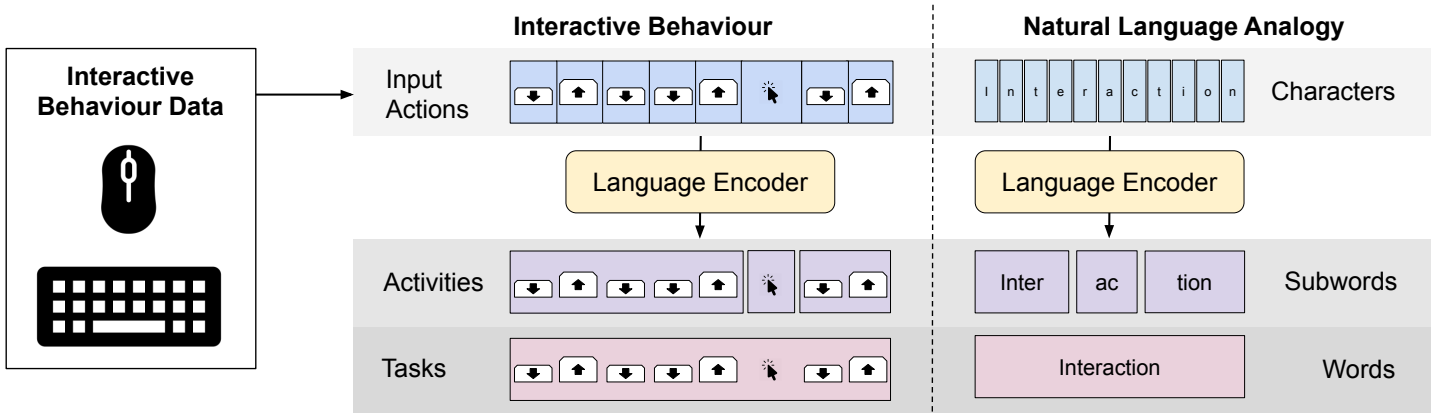
- Extract features from eye and head movements
- Fuse eye and head features to recognise user tasks



[Hu TVCG'22]

Background

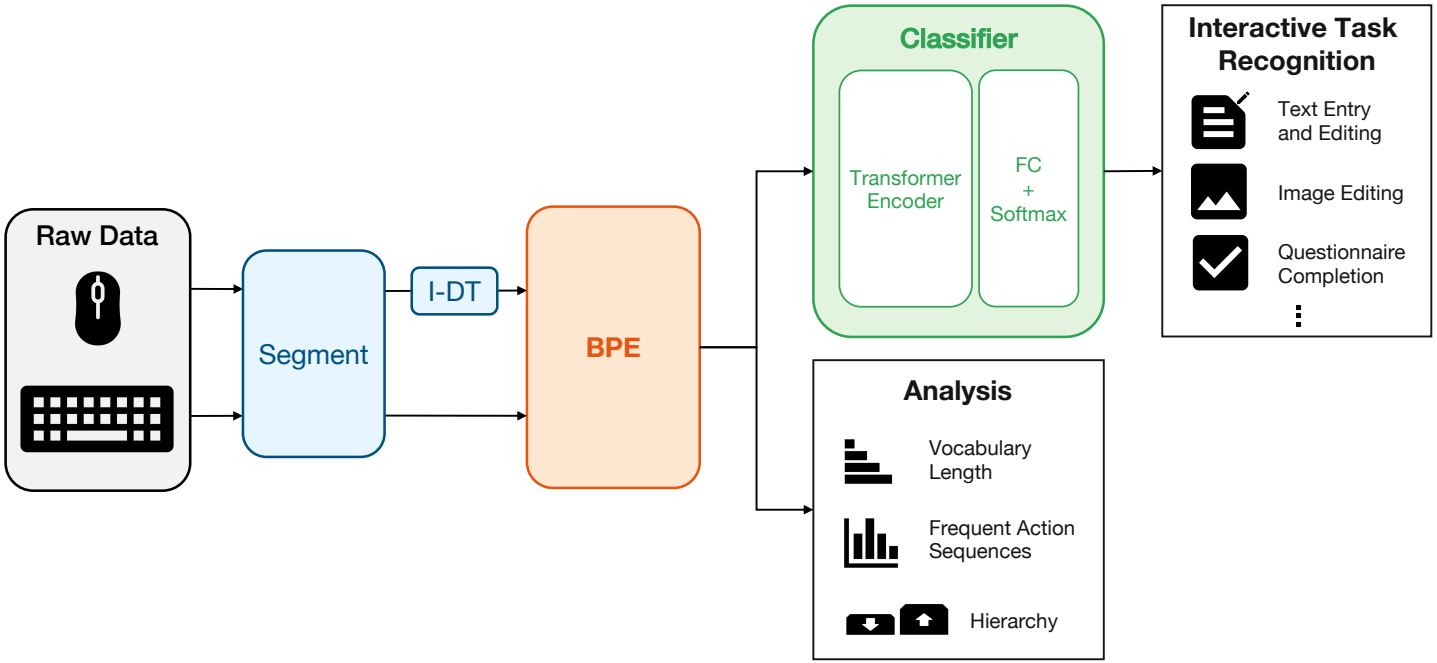
- Interactive behaviour is similar to natural language
- Can NLP methods be used to model interactive behaviour?



[Zhang INTERACT'23 **Best Student Paper Nominees**]

Modelling Interactive Behaviour using NLP Methods

- Byte pair encoding (BPE) to encode mouse and keyboard behaviour
- Transformer to recognise user tasks



[Zhang INTERACT'23 **Best Student Paper Nominees**]

Summary

- Eye and head movement analysis
- Mouse and keyboard behaviour analysis

Future work

- Human motion analysis
- Human interaction intention analysis

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Human-aware Intelligent System

- Gaze-contingent rendering system
- Head-assisted locomotion system

Background

- Virtual reality system requires high refresh rate to ensure user experience
- High refresh rate is computationally expensive

VR rendering [Hu TVCG'20]

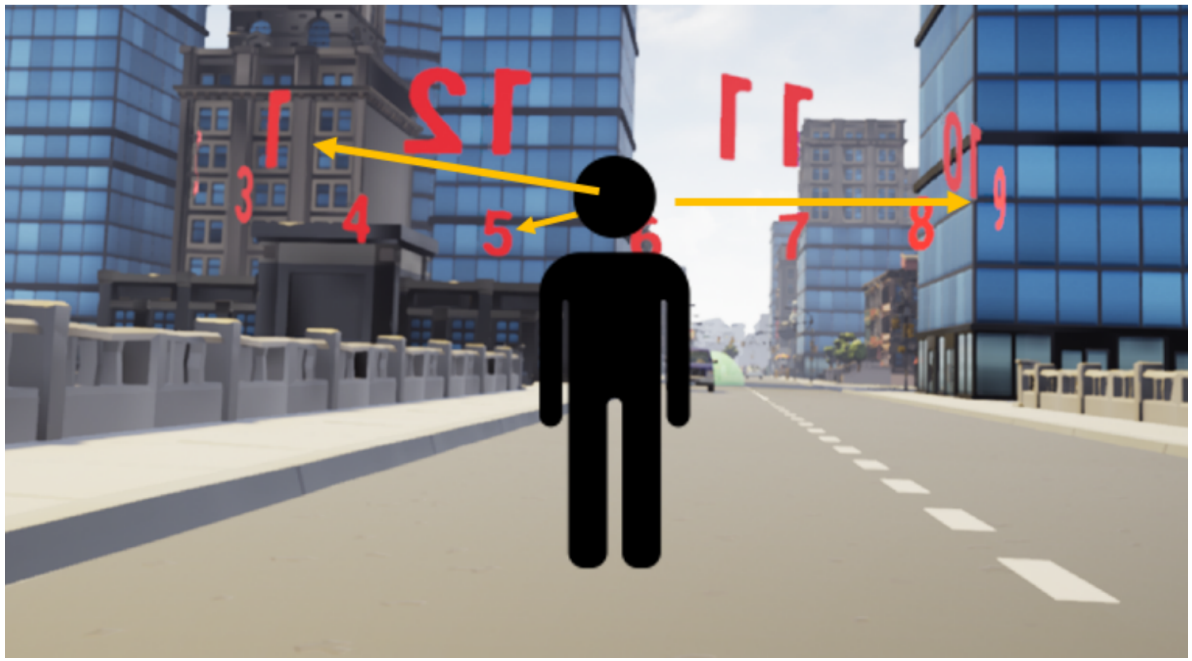
Gaze Estimation for Gaze-contingent Rendering

- Estimate eye gaze in virtual environments
- Apply estimated eye gaze to gaze-contingent rendering

Gaze-contingent rendering [Hu TVCG'20]

Background

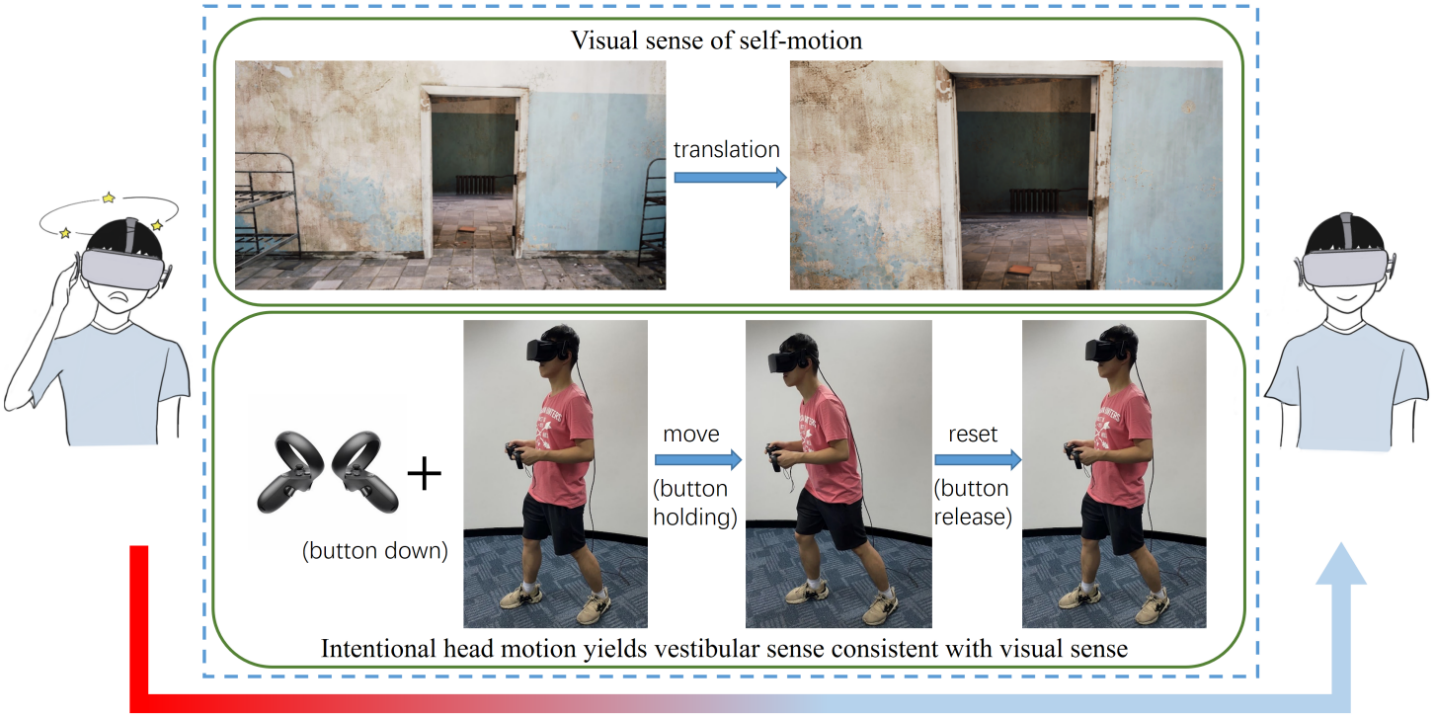
- Locomotion is important for exploring virtual environments
- Cybersickness happens during locomotion



Locomotion in VR [Lin TVCG'22]

Intentional Head Motion-assisted Locomotion

- Cybersickness is correlated with self-motion velocity
- Intentional head motion can reduce cybersickness



[Lin TVCG'22]

Summary

- Gaze-contingent rendering system
- Head-assisted locomotion system

Future work

- Intention-aware adaptive system
- Low-friction predictive interface

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Conclusion

Towards Human-aware Intelligent User Interfaces

- Human behaviour estimation and prediction
- Computational human activity analysis
- Human-aware intelligent system

Q & A

Any question?

Acknowledgement

Thank you!

References i

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