Using 3D heatmaps to visualize the gaze distributions of observers watching a moving subject

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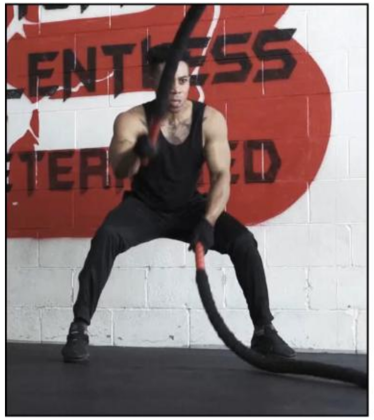

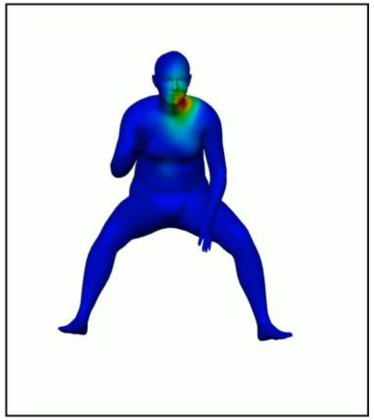

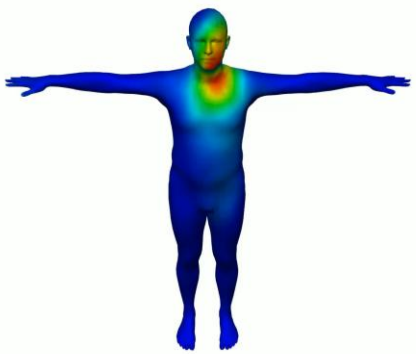

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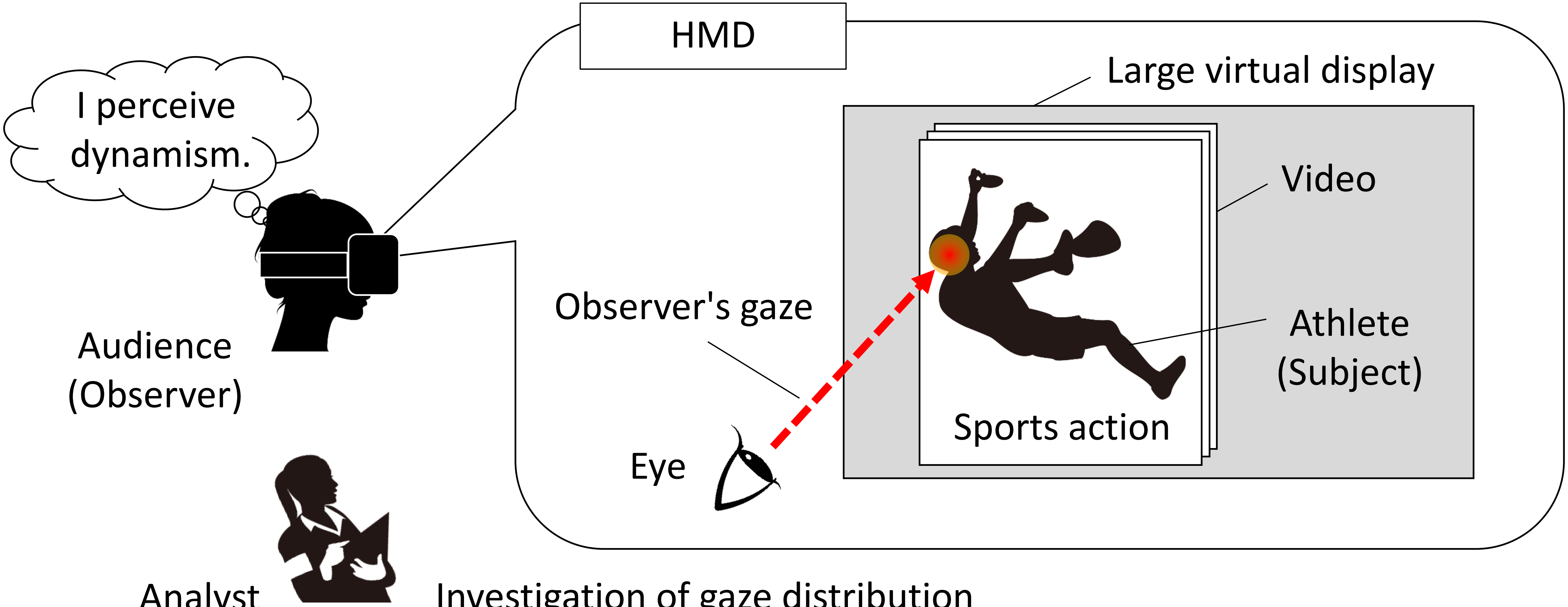
Introduction (1/2)

Sports video content on a virtual large display has been eagerly anticipated.



Investigation of gaze distribution

Introduction (2/2)

When an analyst is studying gaze distribution, there is a need to visualize in an easy-to-understand manner which body part an observer's gaze is focused on.

A **2D heatmap** superimposed on a still image is commonly used to visualize the gaze distribution. [Piers+, Evolution and Human Behavior, 2009] [Irvine+, Body Image, 2019] [Nummenmaa+, Archives of Sexual Behavior, 2012]

2D heatmap

However, the posture of a subject performing a sports action continuously changes when a subject in a video is used as the stimulus.

Specifically, to study gaze distribution using a conventional 2D heatmap, differences in the subject's posture at different temporal points in the video must be taken into account. 😢

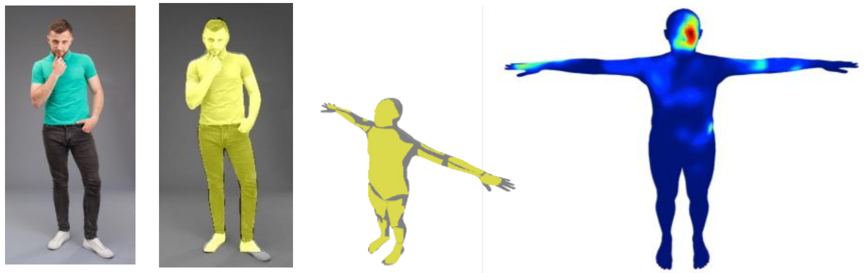
Issues

Visualization method: Analysts can instantly understand the gaze distribution without taking into account differences in posture, even when the subject's posture changes over time.

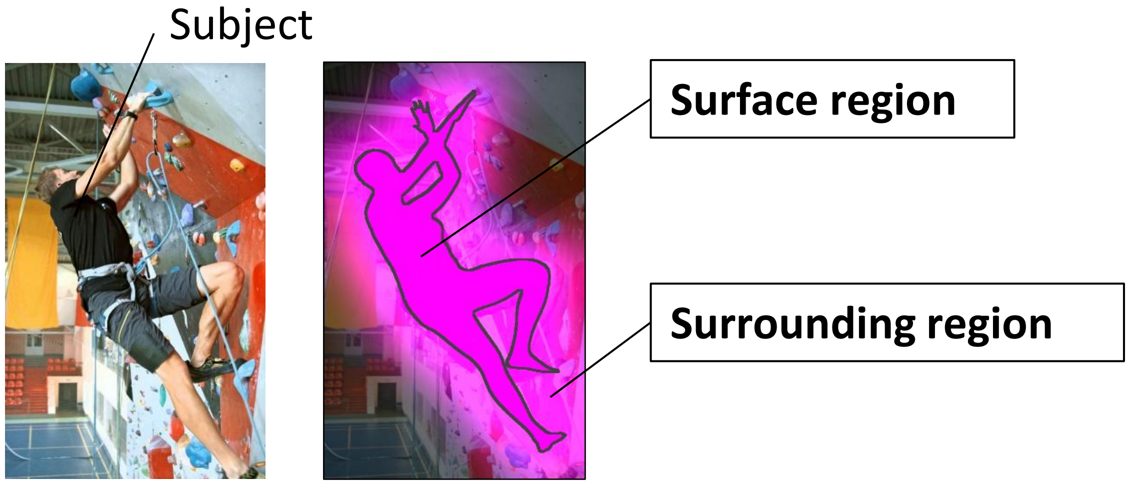
Existing method

[Inoue+, ACPR'23]

A standard human body model with a typical posture is estimated from the subject in a still image, and the gaze distribution on the surface of the body model is visualized using a 3D heatmap.

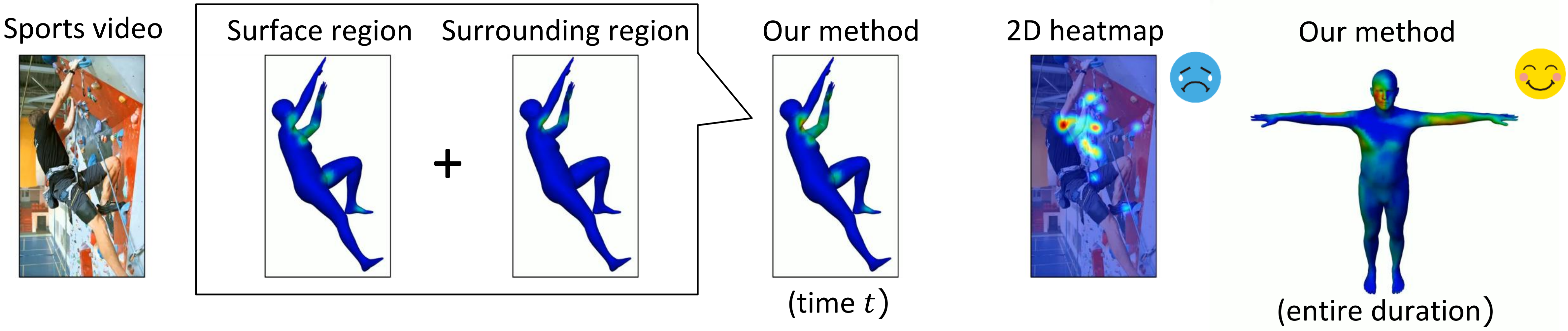


- ✓ Enables the gaze distribution in still images to be evaluated without the need to consider differences in subject posture.
- ✗ Considers only subjects in still images, not subjects in videos, who continuously change their posture.
- ✗ Does not visualize the gaze measured in the surrounding regions because it visualizes only the gaze measured in the subject's surface region.



Purpose

We propose a method to visualize the gaze distribution measured in a subject's surface and surrounding regions using a 3D heatmap in which the subject's posture is standardized over time.

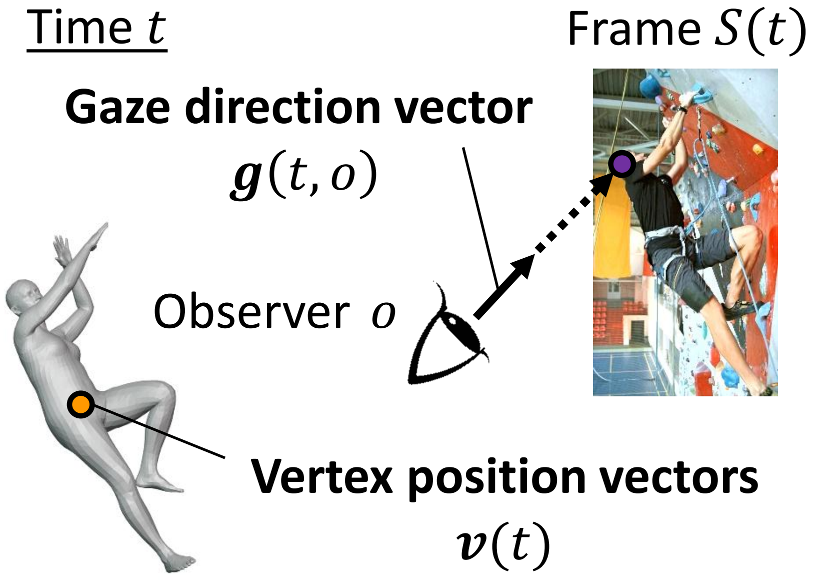


- ✅ Our method visualizes the gaze distribution in both the surface and surrounding regions as a 3D heatmap.
- ✅ Our method visualizes the gaze distribution throughout the entire duration of the video with changes in the subject's posture over time.

Overview of the existing method [Inoue+, ACPR'23]

STEP 1

The eye tracker measures the gaze direction vector $\boldsymbol{g}(t,o)$.

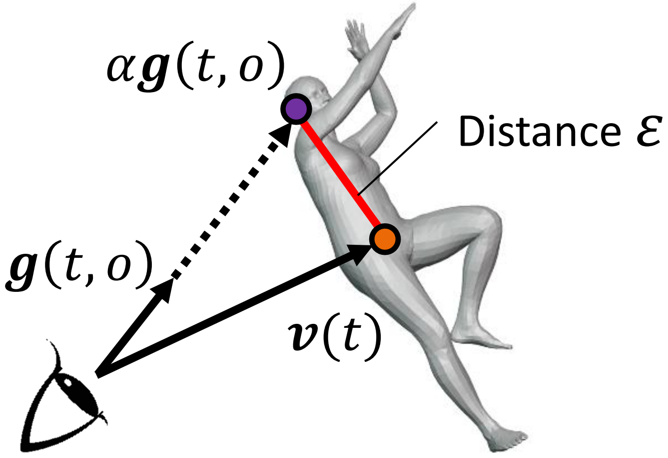


SMPL: Human body model
Posture and body shape parameters
[Matthew+, SIGGRAPH'15]

STEP 2

The **level of attention** is calculated.

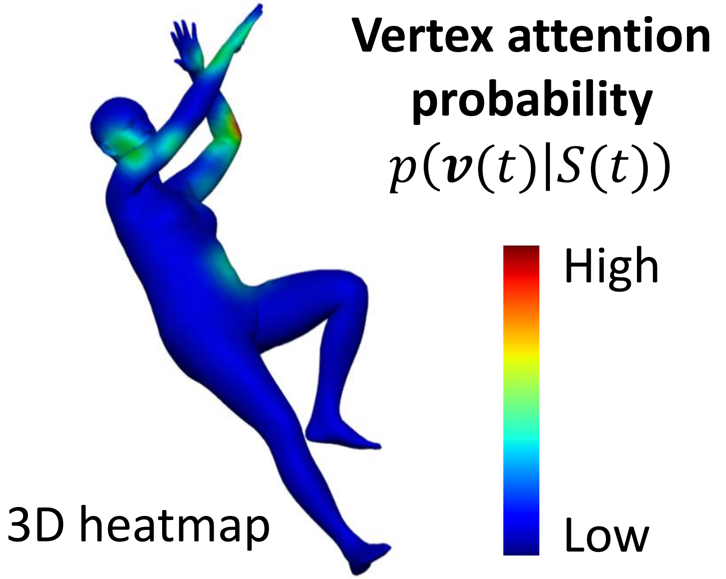
$$d(\boldsymbol{v}(t), \boldsymbol{g}(t,o)) = \exp(-\frac{\varepsilon^2}{2\sigma^2})$$



Smaller ε indicates higher attention.
Larger ε indicates smaller attention.

STEP 3

The vertex attention probability $p(\boldsymbol{v}(t)|S(t))$ is calculated using attention d.

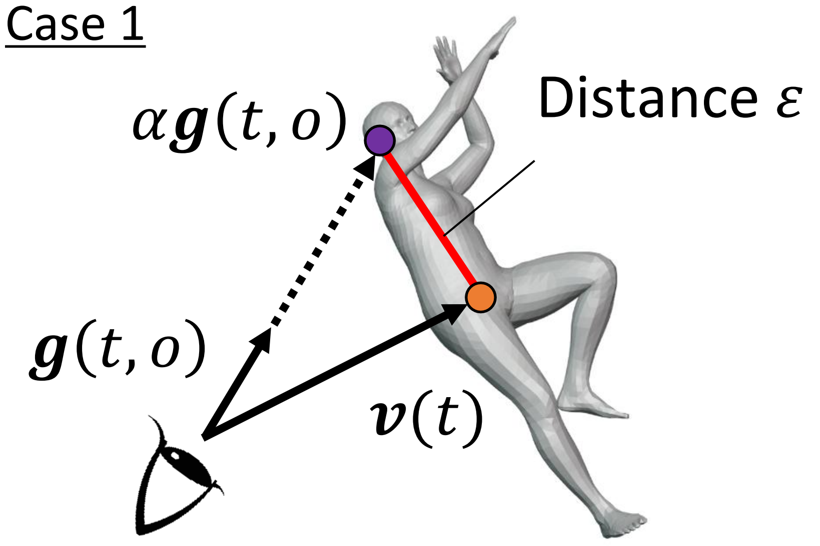


How much the gaze is focused on each vertex $\boldsymbol{v}(t)$ of the body model.

How the existing method handles the gaze

The gaze direction vector $\alpha \boldsymbol{g}(t, o)$ is calculated under the strong constraint that it must intersect with the surface of the human body model.

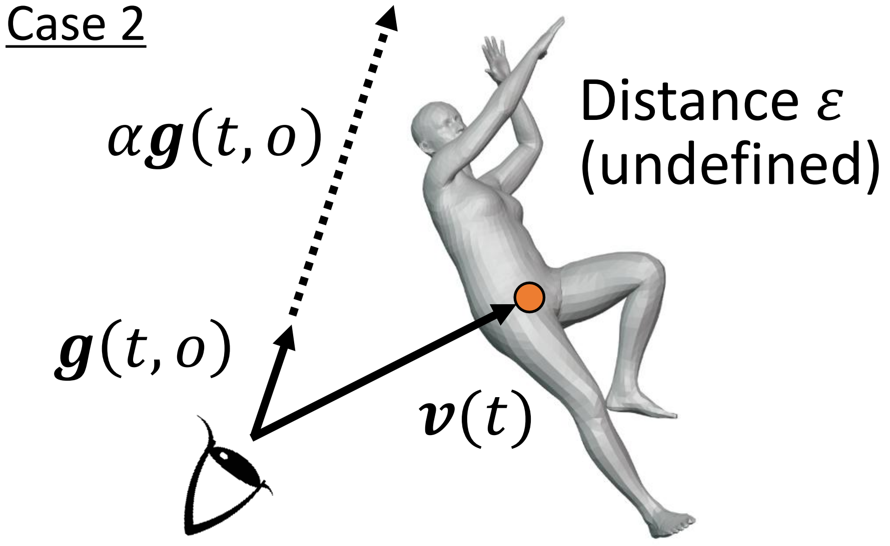
Surface region



Attention $d(\boldsymbol{g}(t, o), \boldsymbol{v}(t))$

Computable

Surrounding region



Attention $d(\boldsymbol{g}(t, o), \boldsymbol{v}(t))$

Uncomputable

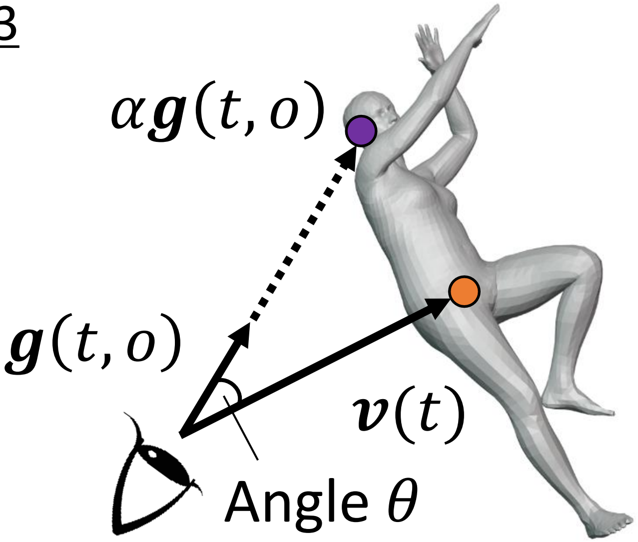
When gaze is measured in the surrounding region, the existing method's 3D heatmap does not adequately visualize the gaze distribution.

Attention to the surface and surrounding regions

Our method uses the angle θ between the gaze direction vector $\boldsymbol{g}(t,o)$ and vertex position vector $\boldsymbol{v}(t)$ to calculate the level of attention $a\big(\boldsymbol{g}(t,o),\boldsymbol{v}(t)\big)$.

Surface region

Case 3

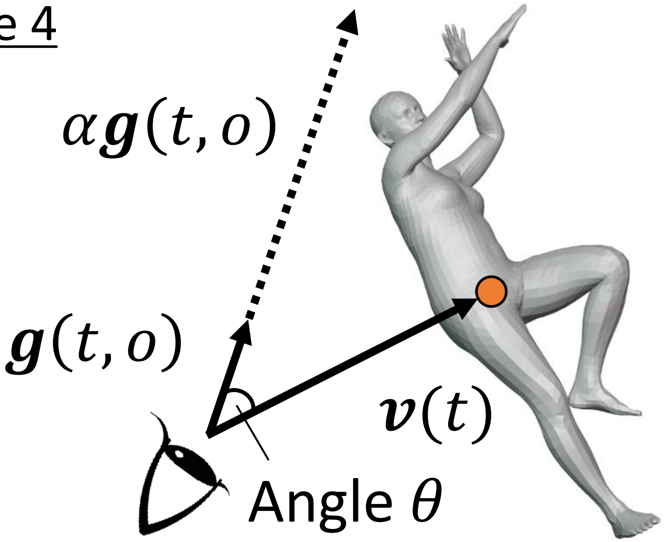


Attention $a\big(\boldsymbol{g}(t,o),\boldsymbol{v}(t)\big)$

Computable

Surrounding region

Case 4



Attention $a\big(\boldsymbol{g}(t,o),\boldsymbol{v}(t)\big)$

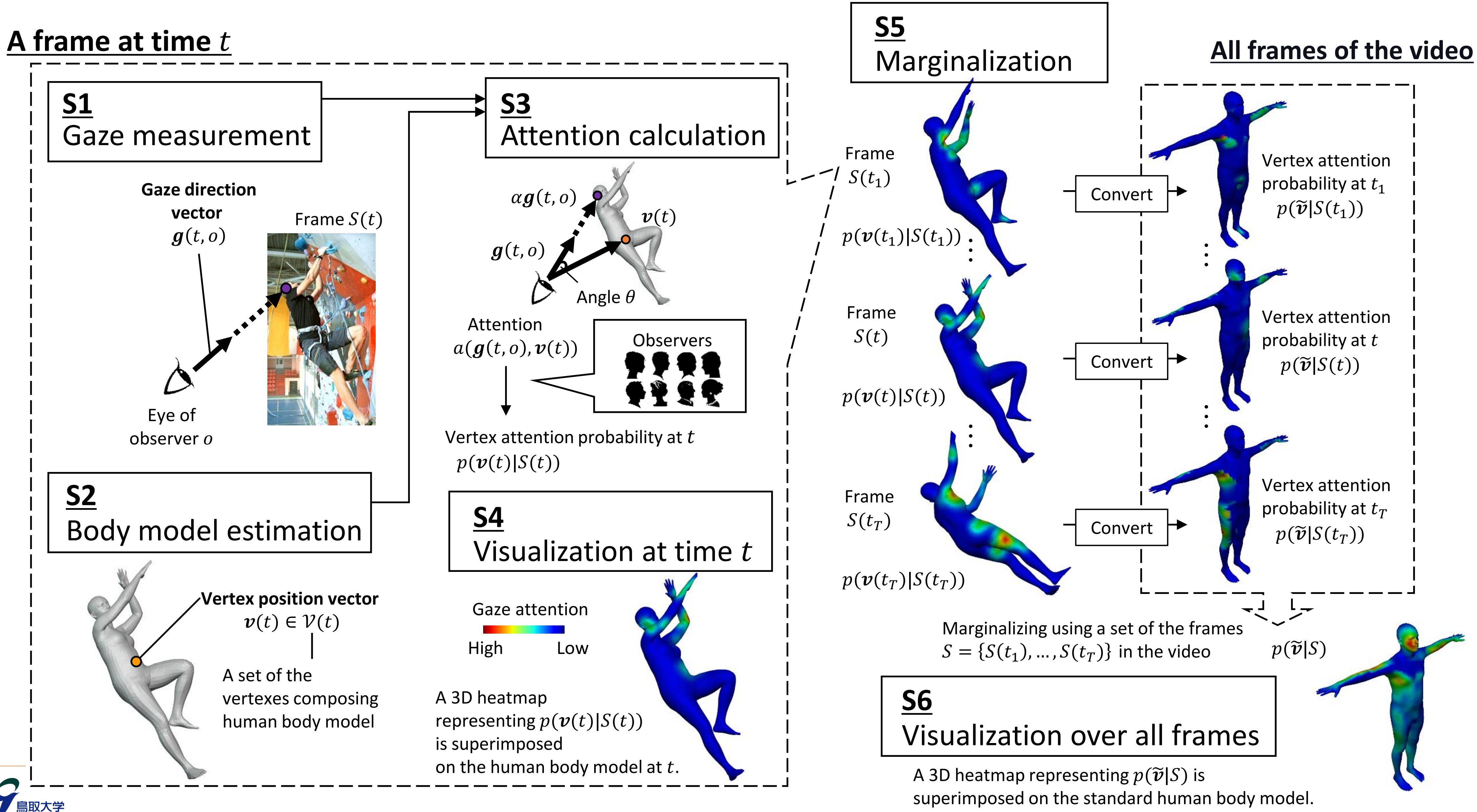
Computable

Surface region

Surrounding region

Our angle-based method can simultaneously handle surface and surrounding regions when visualizing the gaze distribution using a 3D heatmap.

Overview of our method

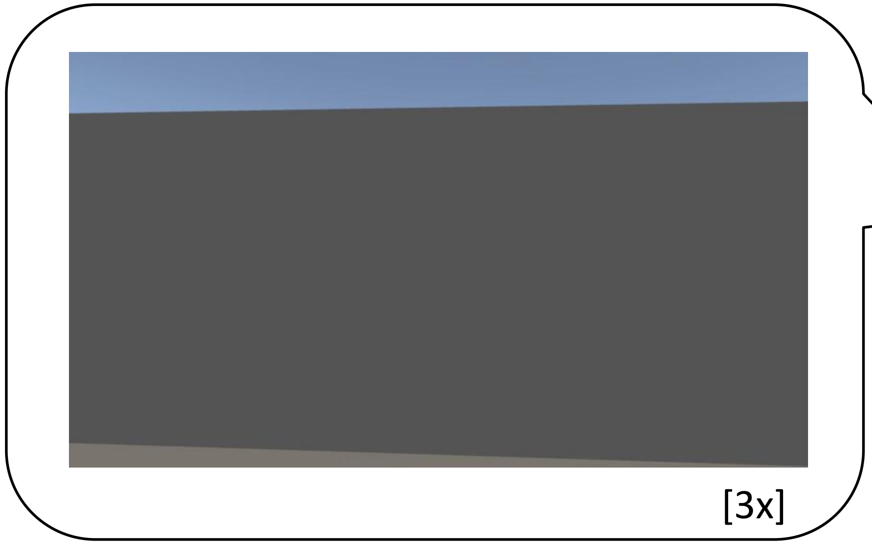


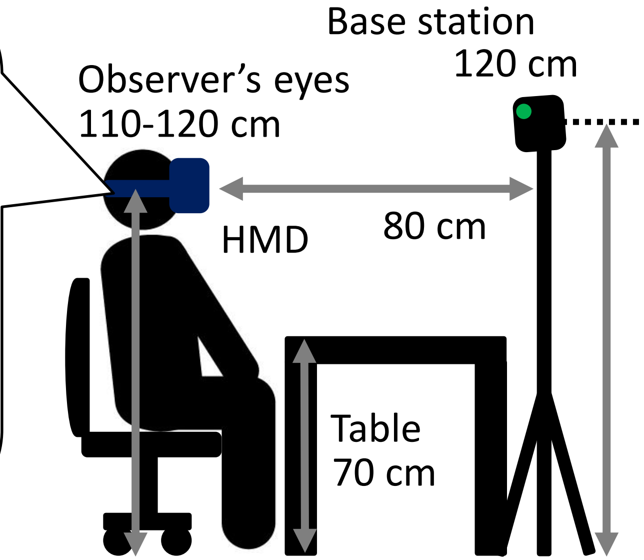
Setup

- Twenty-four observers (12 male, 12 female, mean age 23.6 $\pm$ 2.0 years)

- HMD (VIVE Pro Eye, HTC) with a built-in eye tracker

  Asked observers whether they were affected by the dynamism in the subject's movements.





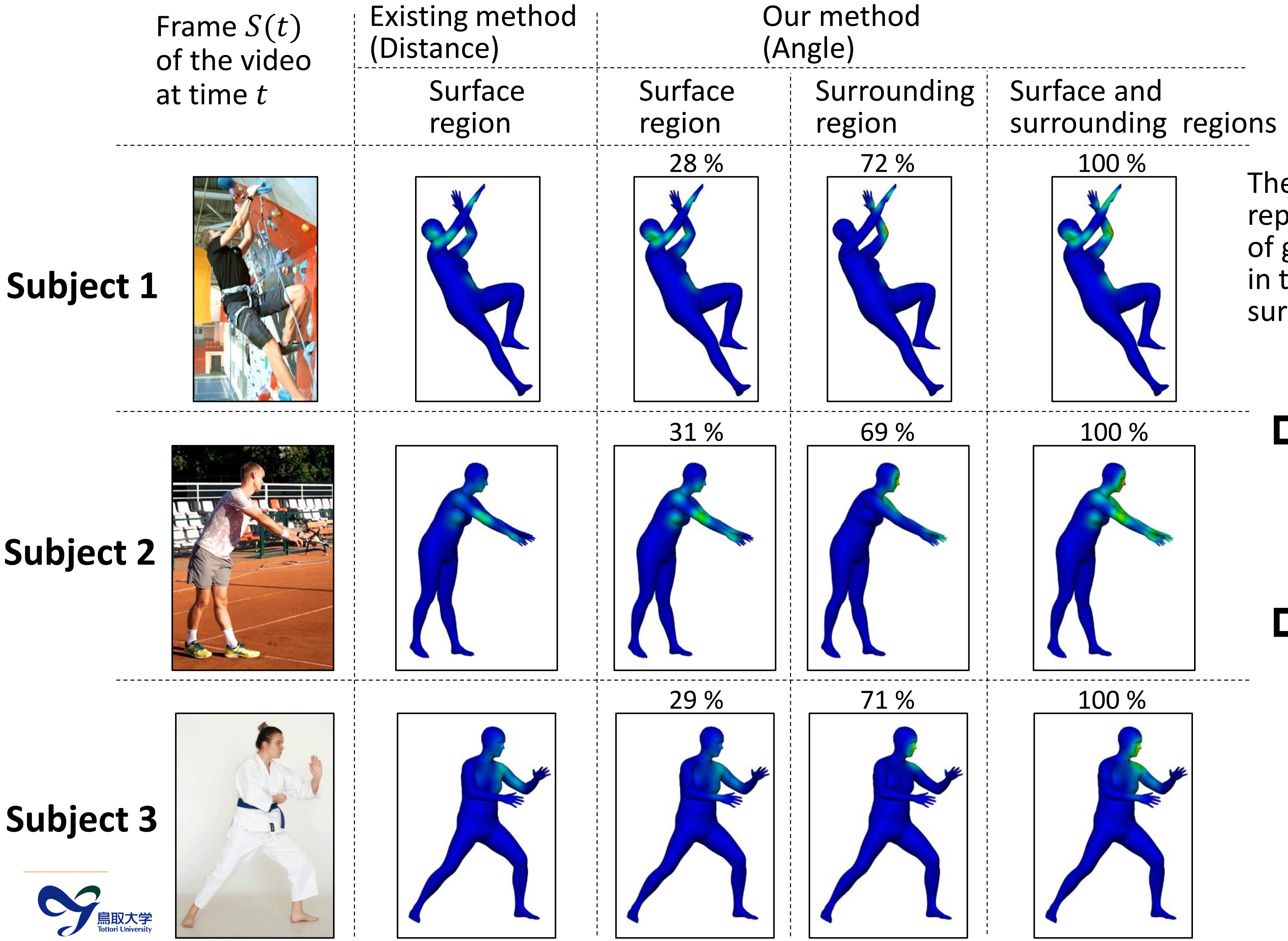
- Stimulus sports videos

Subject 1 climbed a wall.

Subject 2 hit a ball with a tennis racket.

Subject 3 performed martial arts kicks.

Visualization at each time point

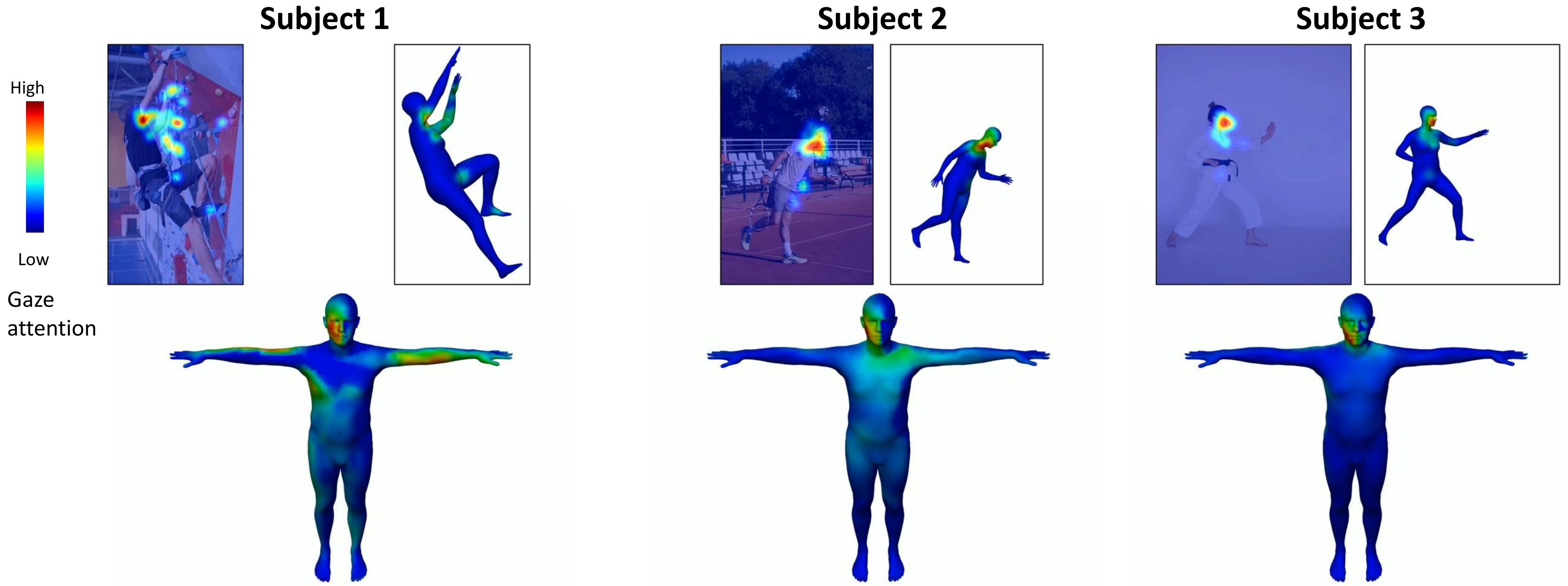


The numbers at the top represent the percentage of gaze samples acquired in the surface region or surrounding region.

- Both methods are equally expressive when visualizing gaze distributions measured on the surface regions.
- The gaze distribution measured in the surrounding region can detect trends overlooked when the gaze distribution is measured in the surface region alone.

Visualization over the entire duration of the video

When an analyst would like to understand where on the subject's body the observers were looking throughout the entire duration of the video, these heatmaps require a detailed memorization of the body parts the gazes were focused on at each video frame.

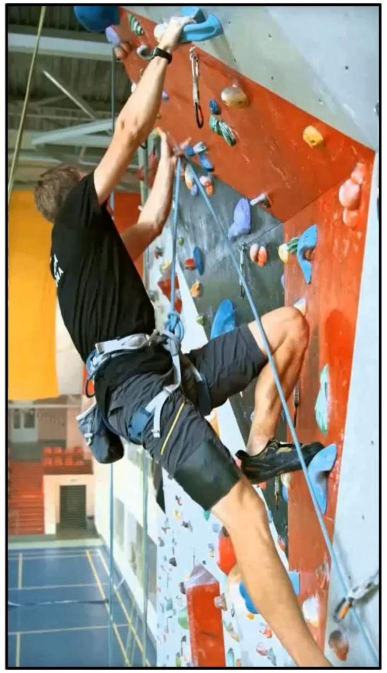


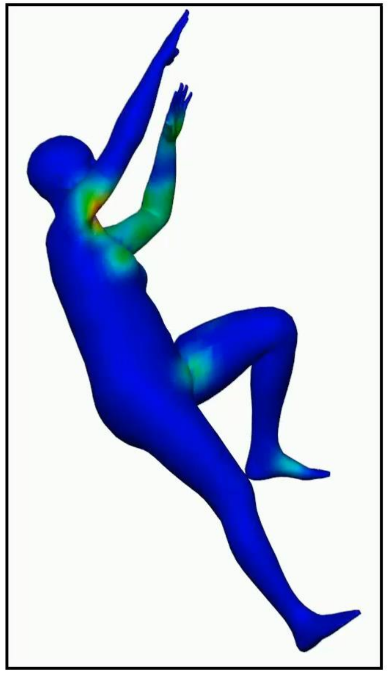
The visualization of the 3D heatmap using our method normalizes the posture, allowing the analyst to understand at a glance where the observers were looking at the subject's body throughout the entire video.

Conclusions

We proposed a method to visualize the gaze distribution of observers asked to assess whether they were affected by the dynamism of a subject's movement in a sports video.

The gaze distribution measured on the subject's surface and in the surrounding regions is visualized using a 3D heatmap in which the subject's posture is standardized over time.





Future work

- We intend to develop a visualization method for videos with multiple subjects.
- We plan to expand our quantitative evaluations through user feedback.