Heatmap overlay using neutral body model for visualizing the measured gaze distributions of observers

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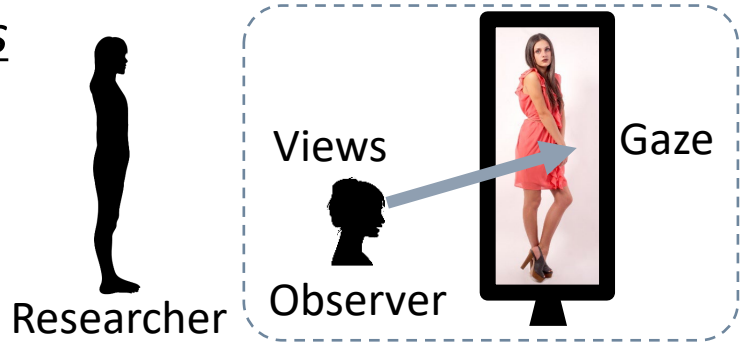
Introduction

Eye-tracking researchers measure and compare the gaze distributions of people, because the gaze distributions indicate the behavior of the observers when they view the bodies of other people.

Measures



Compares

Ex. We consider how to compare whether there are differences in the measured gaze distributions of observers viewing an attractive subject.

- Both hands down
- Slender

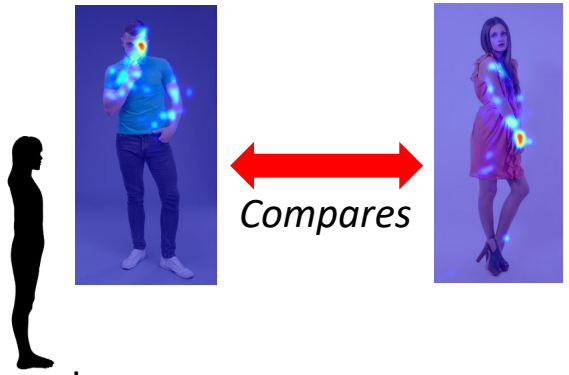
- One hand up
- Muscular

The researchers need a visualization method that can directly compare the gaze distributions among subjects, even when they have different body poses and body shapes.

Existing methods

- 2D heatmaps are often superimposed on images to visualize where an observer's gaze focuses on a subject. [L. Nummenmaa 2012], [K. R. Irvine 2019]
  - ✗ A visualization that superimposes 2D heatmaps is time-consuming for the researchers.

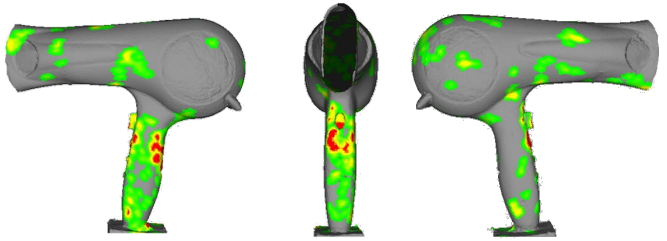
    Ex. The researchers must pay attention to the different poses of the hands and arms and the different body shapes of the man and woman.



- Other visualization methods have been proposed in which 3D heatmaps representing the gaze distributions are superimposed on the surface of artificial objects by aligning the shapes of known objects.

[X. Wang 2016]

[R. Takahashi 2018]



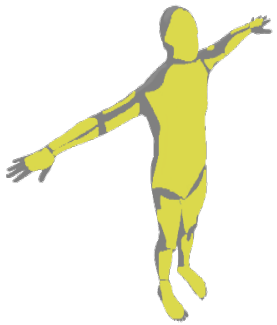
  - ✗ Applying these methods to human subjects is restricting because humans are non-rigid and have various body shapes in different poses.

Purpose

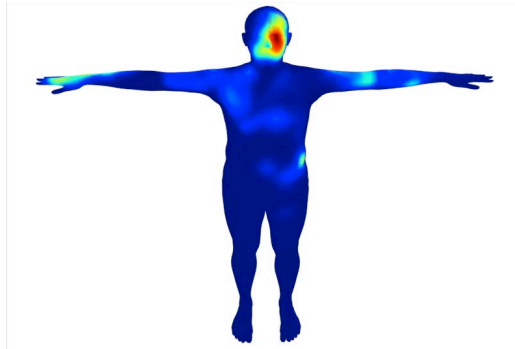
We propose a visualization method that superimposes 3D heatmaps on the surface of a neutral human body to compare the locations of observer gazes directly when the observers view subjects in images.

2D heatmap

+



Neutral human body model



Our 3D heatmap

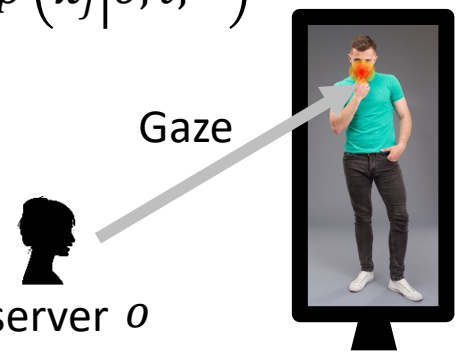
We use a neutral human body model with a body pose and shape that are normalized among subjects.

- ✓ Our method allows eye-tracking researchers to directly compare the gaze distributions on the common 3D human model, even if the body poses and shapes of the subjects differ.

Our visualization method

S1. Pixel attention probability

$p\left(\boldsymbol{x}_j \middle| o, t, \mathcal{I}\right)$



Represents how much the gazes focus on each pixel $\boldsymbol{x}_j$

Time t

Subject region in the image $\mathcal{I}$

S2. Vertex attention probability

$p\left(\boldsymbol{v}_l \middle| o, t, \mathcal{I}\right)$

Represents how much the gazes focus on each vertex $\boldsymbol{v}_l$ of the neutral human body model $\mathcal{V}$

Marginalized by $o \in \mathcal{O}$ and $t \in \mathcal{T}$

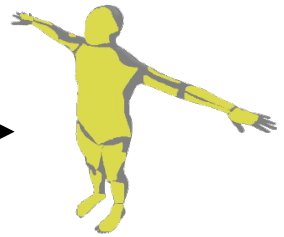
Set of observers $\mathcal{O}$

$p(\boldsymbol{v}_l|\mathcal{I})$

Set of times $\mathcal{T} = \{1, \cdots, T\}$

Neutral human body model

$\boldsymbol{v}_j = m(\boldsymbol{x}_j; \mathcal{I})$



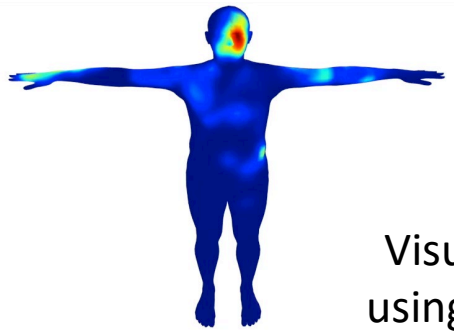
2D position of pixel $\boldsymbol{x}_j$ in $\mathcal{I}$

3D position $\boldsymbol{v}_j$ on the surface of the model

Vertex $\boldsymbol{v}_l \in \mathcal{V}$ of the model

S3. 3D heatmap overlay

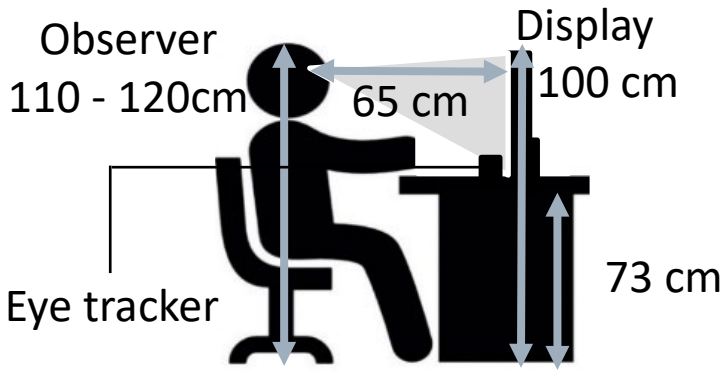
Visualizes $p(\boldsymbol{v}_l|\mathcal{I})$ on the surface of the neutral human body model



Visualization images using the 3D heatmap

Experimental conditions

- We measured observer's gaze distributions.
  - We asked the question "Do you think that the subject's hand are beautiful?".
  - Observers answered the question "yes" or "no".
  - 24 observers:
    12 males, 12 females, 22.4 years old
  - Setting:



Stimulus images


Subject 1

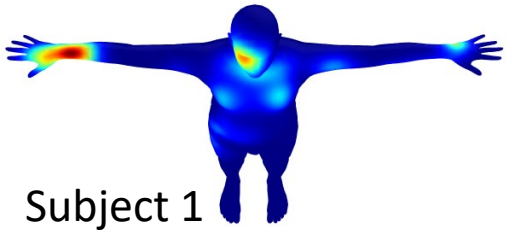
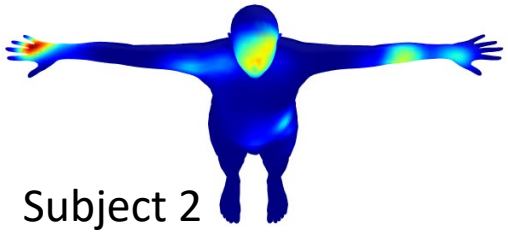
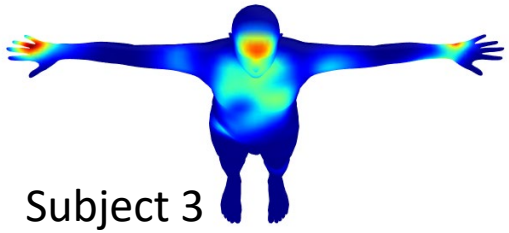

Subject 2


Subject 3

- We evaluated the effectiveness of our method using visualization images.
  - M_{2d} (Conventional method): 2D heatmap representing the *pixel* attention probability
  - M_{3d} (Our method): 3D heatmap representing the *vertex* attention probability

Visualization results

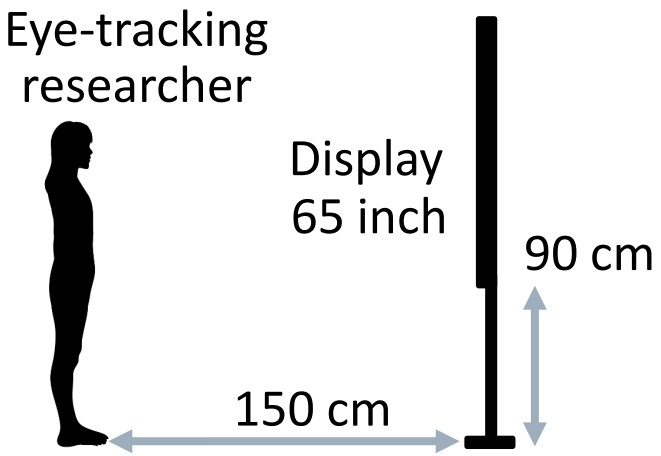
Attention probability:
Low  High

M_{2d} 2D heatmap	Subject 1  Subject 2  Subject 3  ✗ Eye-tracking researchers must consider the differences in the body poses and shapes because of the variation in the body alignment among subjects.
M_{3d} 3D heatmap (Ours)	 Subject 1  Subject 2  Subject 3 ✓ Eye-tracking researchers only need to compare the same positions on the surface of the model because these 3D heatmaps make the body alignment equal for all subjects.

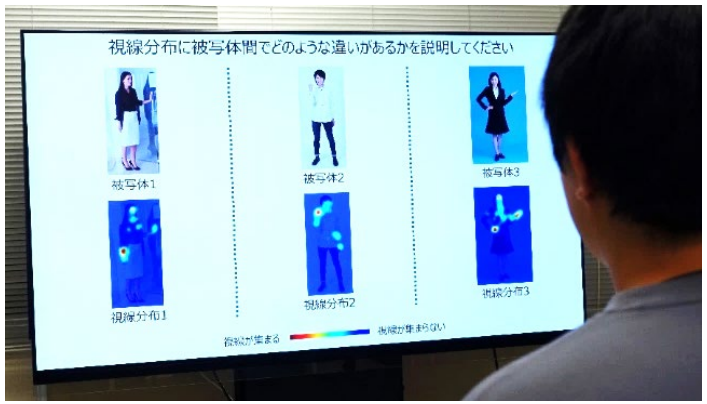
The gaze distributions reveal the gazes most often focus on the hand, followed by the head.
We can reach this conclusion more directly using our method M_{3d} than the conventional method M_{2d}.

Conditions of subjective assessment

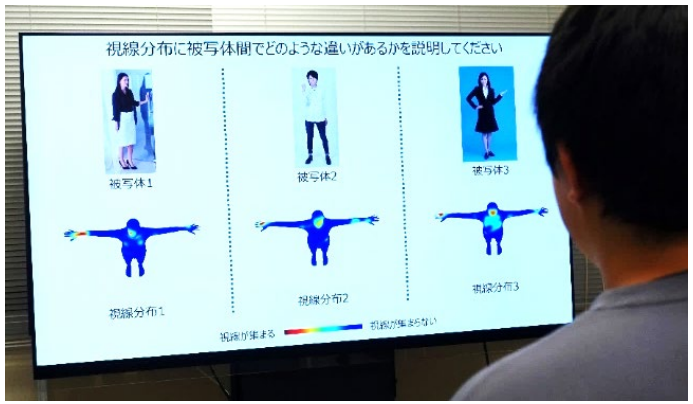
- We conducted a subjective assessment to determine whether the visualization images generated by M_{2d} or M_{3d} enable the gaze distributions for various subjects to be directly compared.
  - 16 young eye-tracking researchers: 13 males, 3 females, 23.4 years old
  - We asked the researchers to choose the visualization images they felt would better directly facilitate the comparison of gaze distributions among the subjects.
  - The researchers replied with one of the following answers: M_{2d}, M_{3d}, or neutral.
  - Setting:



Example of the visualization images on the display

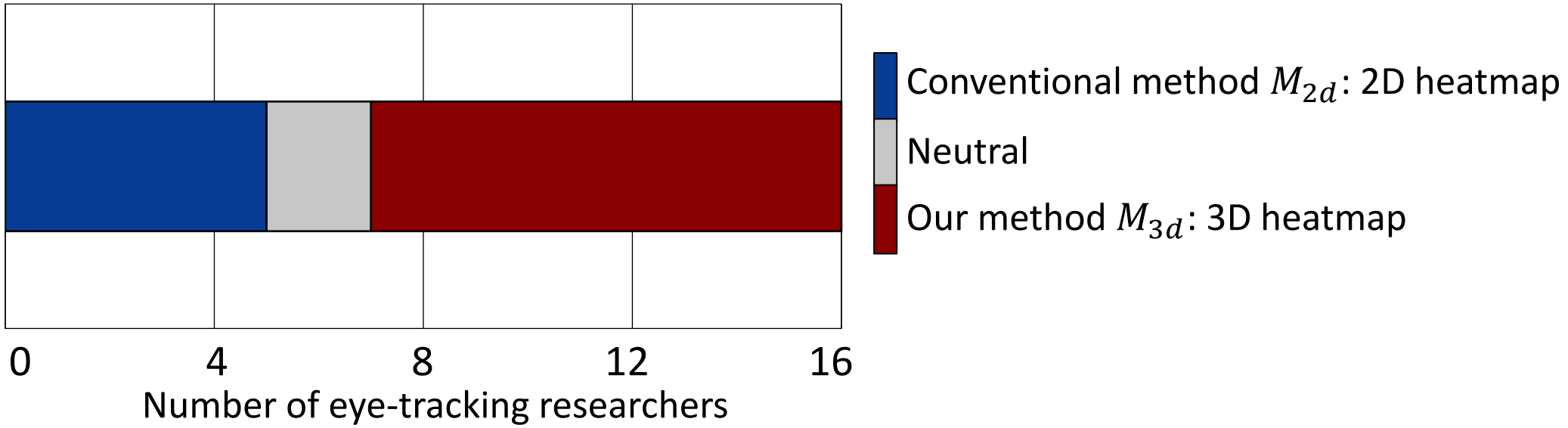


M_{2d}: 2D heatmap



M_{3d}: 3D heatmap

Result of the subjective assessment

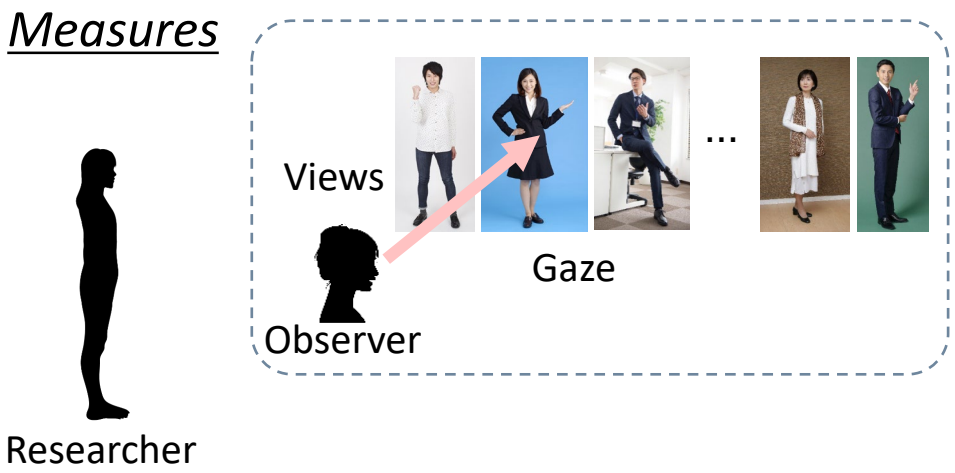


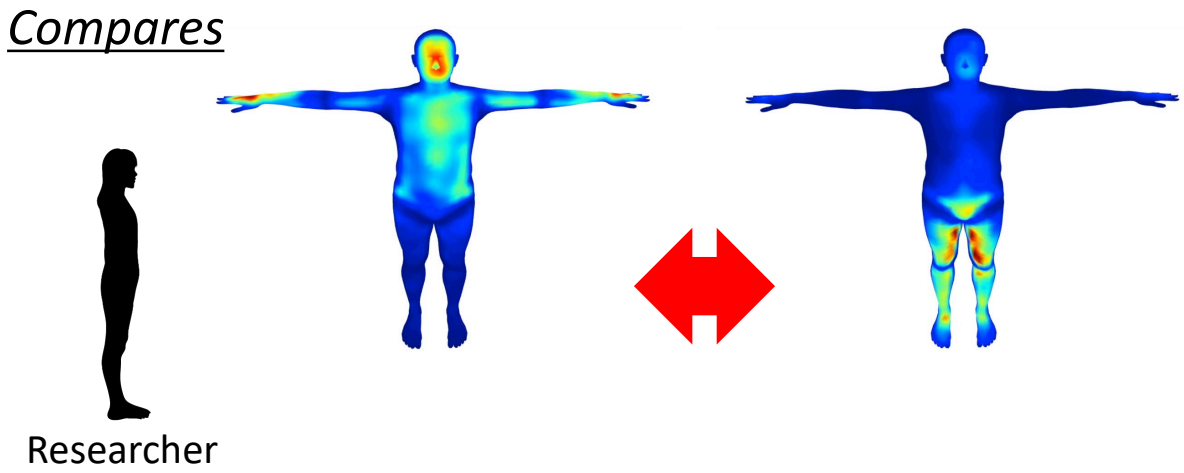
- Our method M_{3d} obtained the highest results.
- Some researchers chose M_{2d} because they were familiar with the 2D heatmaps, which made it easy to identify the body parts focused on by gaze for each subject.

Our method M_{3d} enables eye-tracking researchers to compare differences more directly in the gaze distributions than the conventional method M_{2d}, even when the body poses and shapes are different.

Conclusions

- We proposed a method of superimposing 3D heatmaps on the surface of a neutral human body model to visualize where the gazes of observers focus when they view subjects in images.
- Eye-tracking researchers could directly compare the gaze distributions for the visualization images obtained using our method, even when the body poses and shapes differed among subjects.





Future work

We will expand the evaluation for various shape characteristics, such as the weight of the subjects.