Gait Analysis under MR-simulated Low-Light Environments

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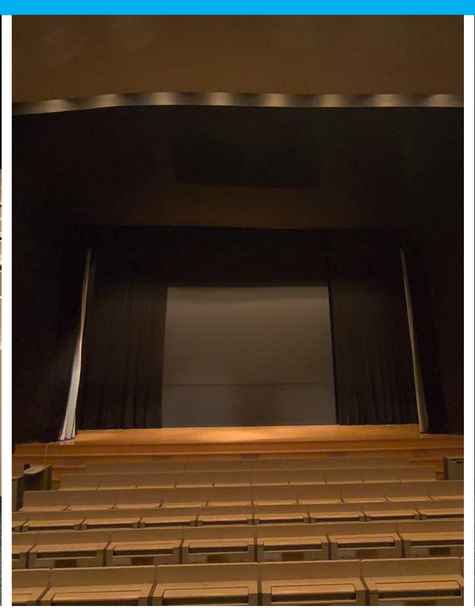
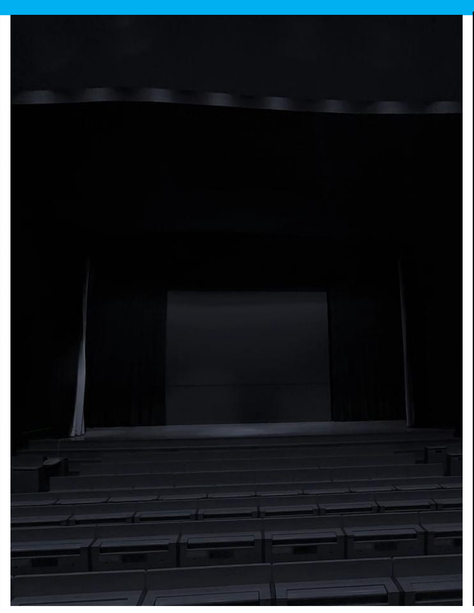
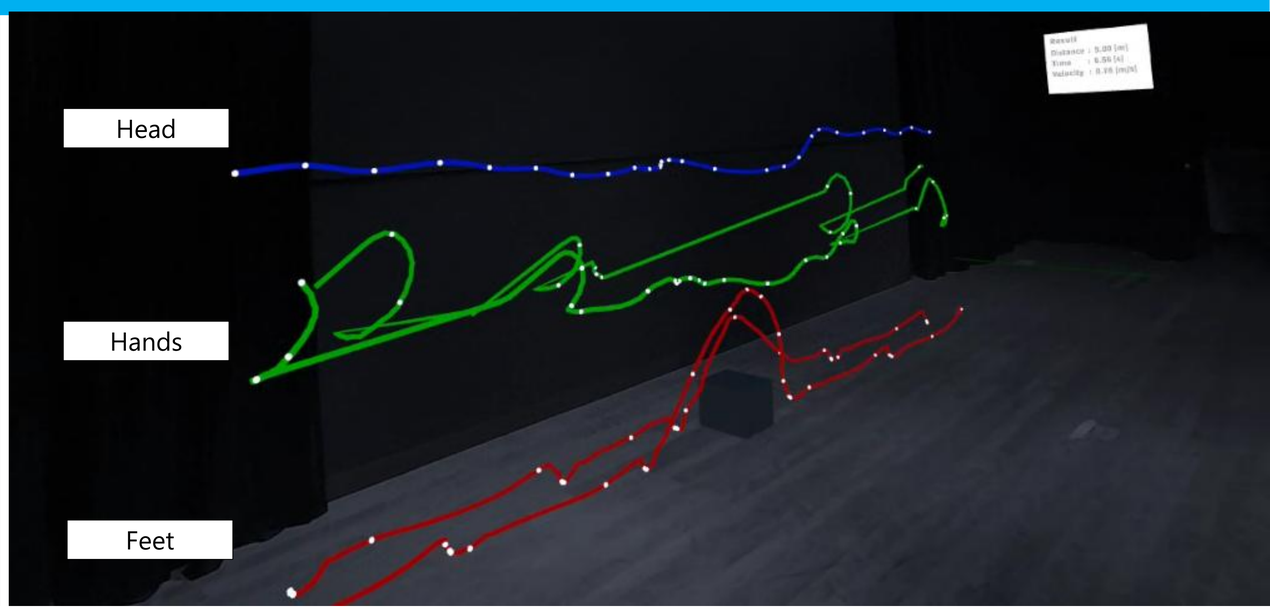






Background :

- It is important to perform gait analysis in low-light environments.
- However, it is difficult to ensure safety and prepare a large dark room.

Goal :

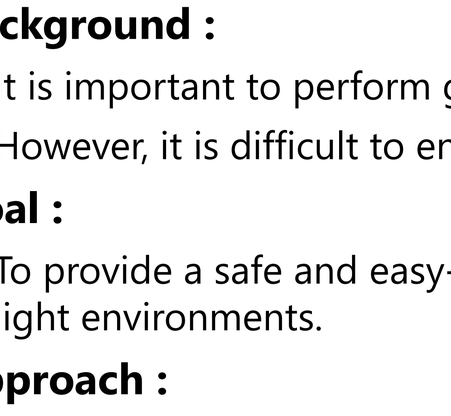
- To provide a safe and easy-to-use gait analysis framework under low-light environments.

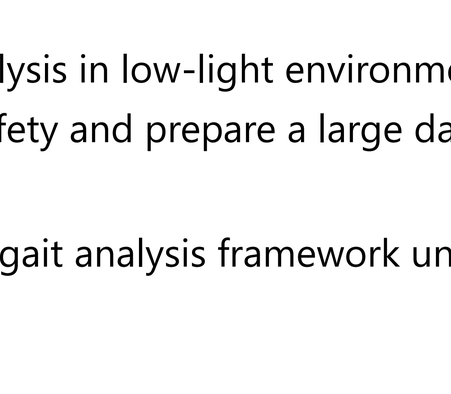
Approach :

- Simulate low-light space by filtering the MR passthrough view.
- Perform 5-m walk test in MR low-light environment.
- Record trajectories of head, hands, and feet.

Set up and low-light simulation

- The user wears Meta Quest 3.
- To capture foot motion, we attach the controllers on the shoes.


Neutral look-up table

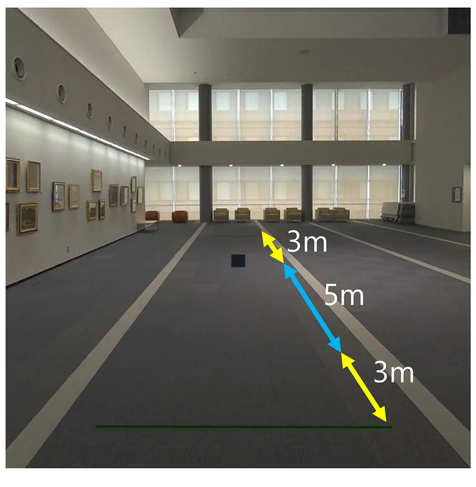

Night scene filter (k = 0.08)

- This device simulate low-light environments applying a night scene filter [1] to passthrough image.
- We implemented using Quest 3's passthrough color look-up table.

$$\mathbf{c} = k\, V\, \mathbf{c}_{blue}$$

$\mathbf{c}$: output pixel color
k : empirically set gain coefficient
V : scotopic luminance [2]
$\mathbf{c}_{blue}$: blueshift vector [1]

MR-based 5-meter walk test



We introduce MR-based 5-m walk test.

- Virtual low-light environment.
- Virtual obstacles.

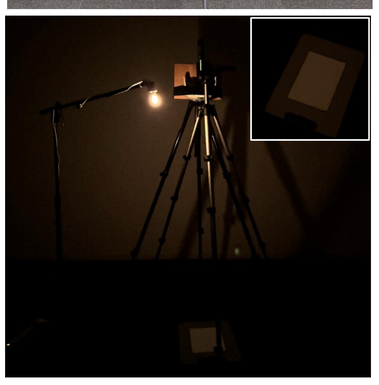
Our system records and visualizes.

- Walking speed and time.
- Trajectories of the head, hands and feet.

→ **Enables detailed gait analysis with safe assistance in bright room.**

References
[1] William B. Thompson, Peter Shirley, and James A. Ferwerda. 2002. A Spatial Post-Processing Algorithm for Images of Night Scenes. Journal of Graphics Tools 7, 1 (2002), 1–12.
[2] G.W. Larson, H. Rushmeier, and C. Piatko. 1997. A visibility matching tonereproduction operator for high dynamic range scenes. IEEE Transactions on Visualization and Computer Graphics 3, 4 (1997), 291–306.

Evaluation of MR Low-Light Environment



Human recognize obstacles by luminance contrast.
We measured floor illuminance and luminance from a white and gray paper.

Conditions :

Bright :
luminance under 520 lux room.

LowLight :
measure luminance under 0.1 lux room.

MR-Pass :
luminance of the passthrough image.

MR-LowLight :
luminance the simulated passthrough image.
(k = 0.001, 0.05, 0.01)

Luminance of each condition is as follows

	Bright	*LowLight*	*MR-Pass*	*MR-LowLight* k=0.01	*MR-LowLight* k=0.005	*MR-LowLight* k=0.001
white	132.767	0.027	47.872	1.240	0.626	0.250
gray	24.930	0.005	16.166	0.381	0.270	0.237
Diff	107.826	0.022	31.707	0.085	0.357	0.013

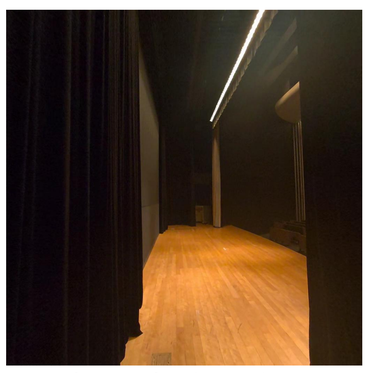
➡ **A gain of 0.001 simulates contrast close to real low-light conditions.**

User Study

The users performed 5-meter walk test twice under six conditions.

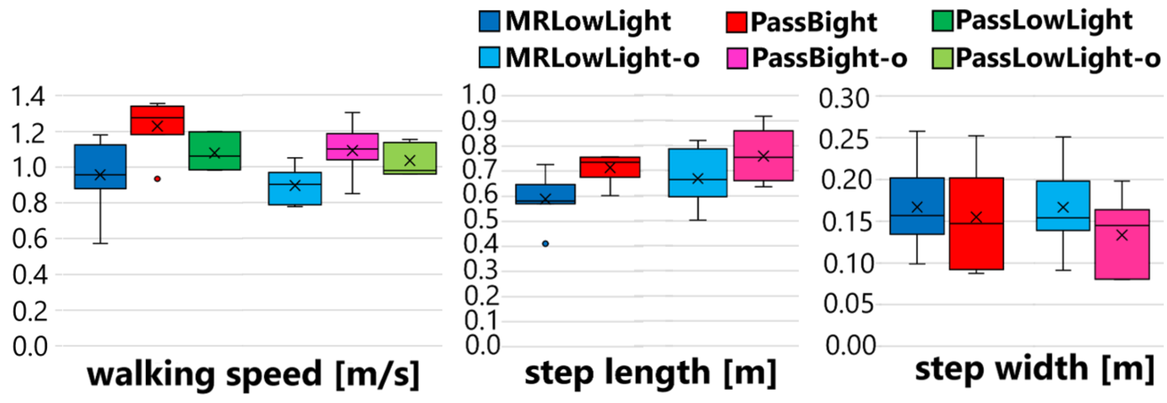
Conditions : ("-o" indicates a 22.86 cm obstacle on the walking path)


MR-simulated low-light environment.


Passthrough view via HMD in bright room.


Passthrough view via HMD in lowlight room.

Result : Seven engineering students participated.



- MR-LowLight : Tendency for reduced walking speed and step length.

→ Careful gait due to visual restriction.

<u>These results suggest that the MR-simulated low-light environment can induce gait changes similar to those in real low-light conditions.</u>