# Human Perception of Weight in Remote Robot System with Force Feedback


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# Outline

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# Background (1/2)

- Remote robot systems with force feedback have been actively researched.

A user can operate a remote industrial robot by using a haptic interface device while watching video.

- The user can perceive the shape, weight, and softness of a remote object.

We expect that the efficiency and accuracy of work can be improved largely.

# Background (2/2)

When we use the remote robot system with force feedback over a network like the Internet, which does not guarantee the Quality of Service (QoS) .

Network delay, delay jitter and packet loss

QoE (Quality of Experience) degradation

To reduce degradation

- QoS (Quality of Service) control
- Stabilization control

To carry out control efficiently

It is necessary to clarify the human perception.

*1 D.Osada *et al.*, Proc. IEEE ICCCS, pp. 158-162, Apr.2018

# Purpose (1/2)

## Previous work

- Investigate human weight perception by using a weight balance system in a networked virtual space by QoE assessment*1.
- The weight balance system is a system in which two users collaborate in a three-dimensional (3D) virtual space to lift a weight vertically.
  - Humans can hardly perceive absolute weight changes lighter than or equal to about 10 gf.
  - Subjects start to perceive the change less than or equal to 20 gf.

- The study is conducted by using the haptic interface device only in a virtual space.
- It is also important to clarify the human perception in a real space.

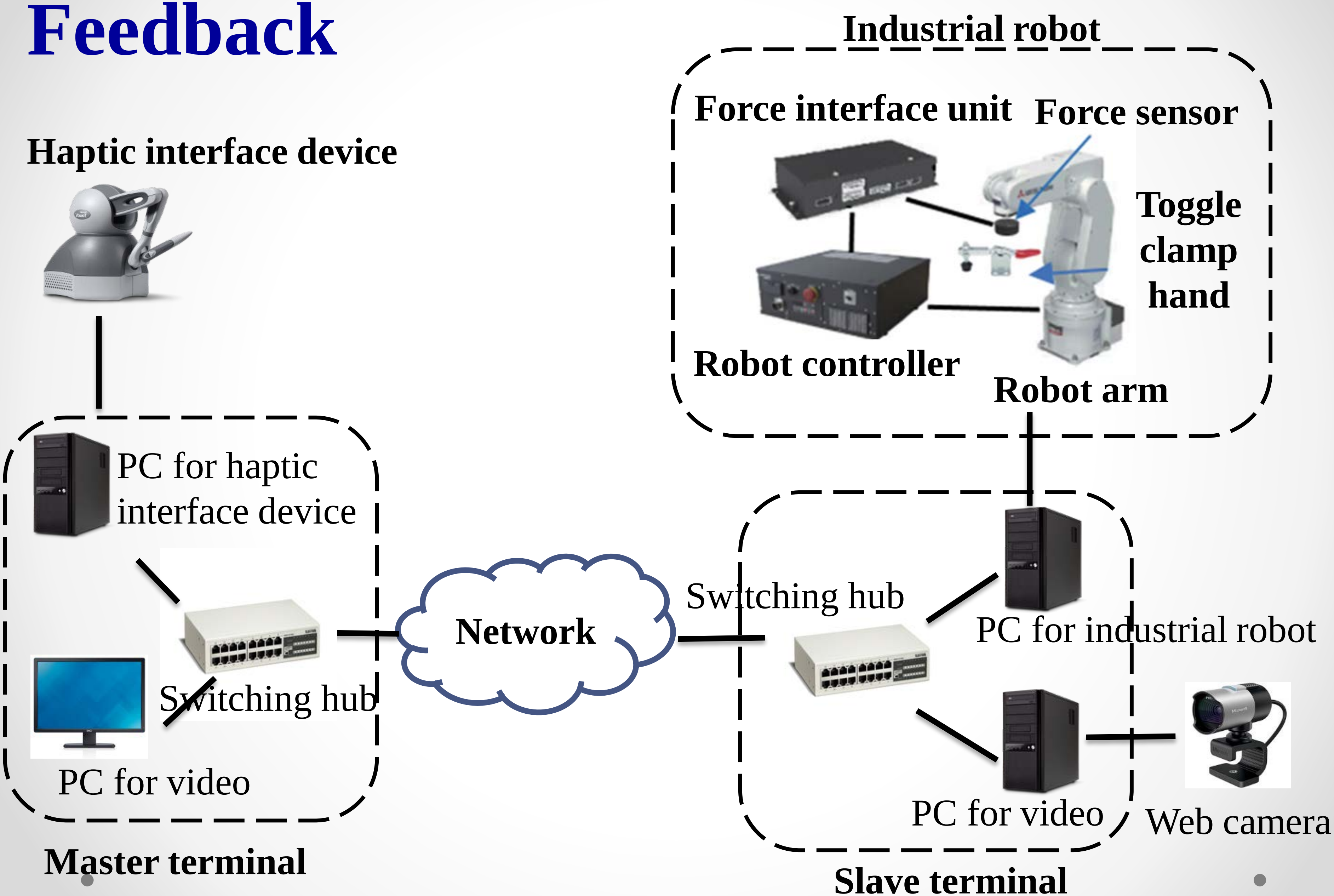
# Purpose (2/2)

**This work**

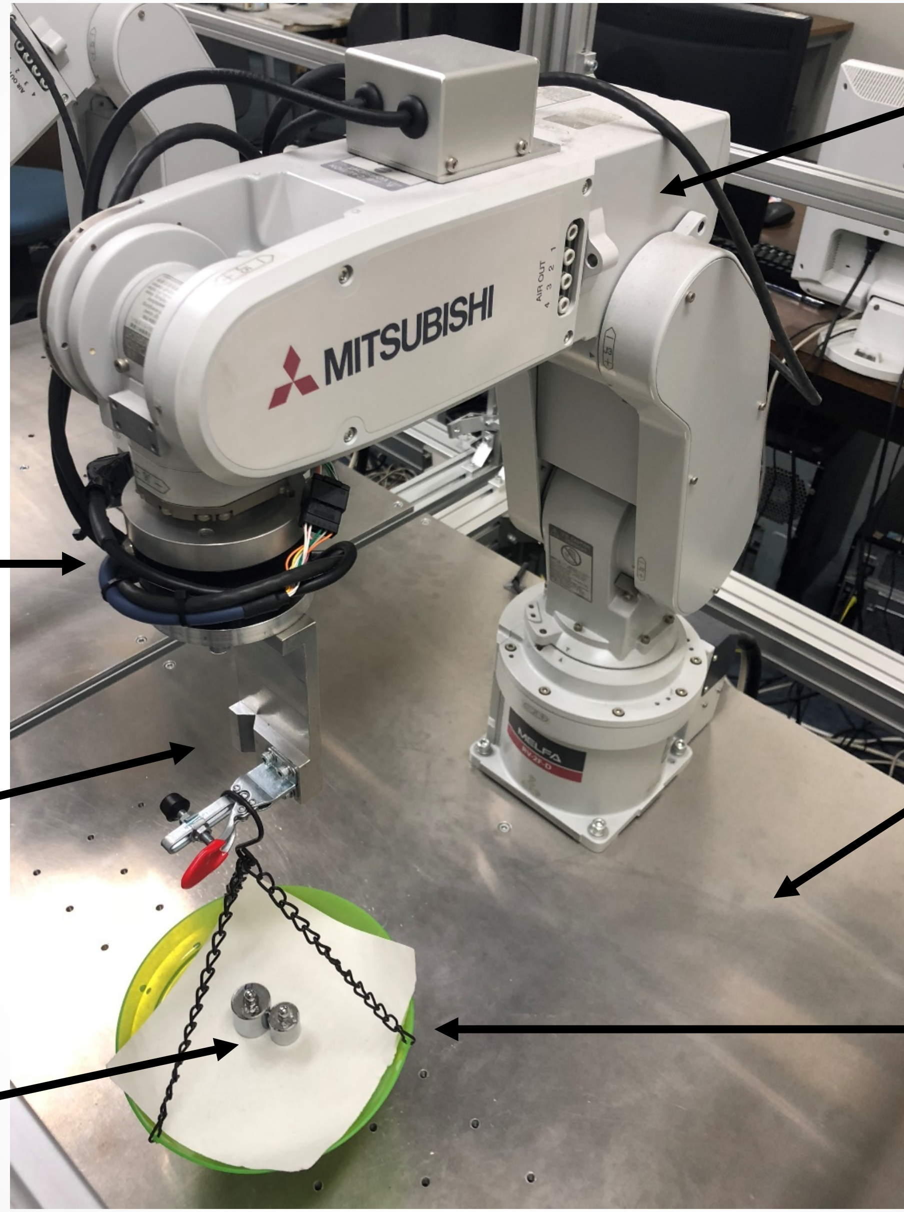
- We investigate human weight perception through the remote robot system with force feedback by QoE assessment in a real space.

- We assess whether each subject can perceive the difference of the weight after changing the weight hung from the industrial robot.

# Remote Robot System with Force Feedback



# Industrial Robot Arm




Industrial robot arm

Force sensor

Metal platform

Toggle clamp hand

Hanging plate

Weights

# Calculate Method of Reaction Force

The reaction force $\boldsymbol{F}_t^{(\mathrm{m})}$ to be outputted thought the device at time t (t ≥1) (ms) is calculated from the value of the force sensor.

$$\boldsymbol{F}_t^{(\mathrm{m})} = K_{\mathrm{scale}}\, \boldsymbol{F}_{t-1}^{(\mathrm{s})}$$

$\boldsymbol{F}_t^{(\mathrm{m})}$ : Reaction force outputted at time t ( ≥ 1)

$\boldsymbol{F}_t^{(\mathrm{s})}$ : Force received from slave terminal at time t ( ≥ 1)

$K_{\mathrm{scale}}$ : Mapping ratio about scale of force

| Force (Robot : Geomagic) |
|---|
| 1 : 1 ($K_{\mathrm{scale}} = 1$) |

Robot: Industrial robot

Geomagic: Haptic interface device

# Calculation for Position of Industrial Robot

At the slave terminal, the industrial robot arm is operated according to the position information transmitted from the master terminal.

$$\boldsymbol{S}_t = \boldsymbol{M}_{t-1}$$

$\boldsymbol{S}_t$ : Position vector of industrial robot at time t ( $\geq$ 1)

$\boldsymbol{M}_t$ : Position vector of haptic interface device at time t ( $\geq$ 1)

| **Work space (Robot : Geomagic)** |
| --- |
| 1 : 1 |

Robot: Industrial robot
Geomagic: Haptic interface device

# Assessment Method (1/3)

- Each subject holds the stylus of the haptic interface device and then keeps it at the same position.
- We change the weight of the hanging plate from the force sensor at a time.
- The subject feels the reaction force depending on the force sensor of the industrial robot arm.
- The weight before change is called the *standard weight* here.
- The subject is asked to answer whether the weight has been changed from the standard weight. There are three choices for the subject: “lighter,” “no change,” and “heavier.”

# Assessment Method (2/3)

| Standard weights | Range of change | Total times |
|---|---|---|
| 50 gf | −50 gf～+50 gf | 33 times |
| 100 gf | −70 gf～+70 gf | 45 times |
| 150 gf | −70 gf～+70 gf | 45 times |
| 250 gf | −70 gf～+70 gf | 45 times |

- The negative value means that the weight after change is lighter than the standard weight, and the positive value does that the weight after change is heavier.
- The assessment was conducted by 15 subjects (8males and 7 females) whose ages were between 21 and 26.

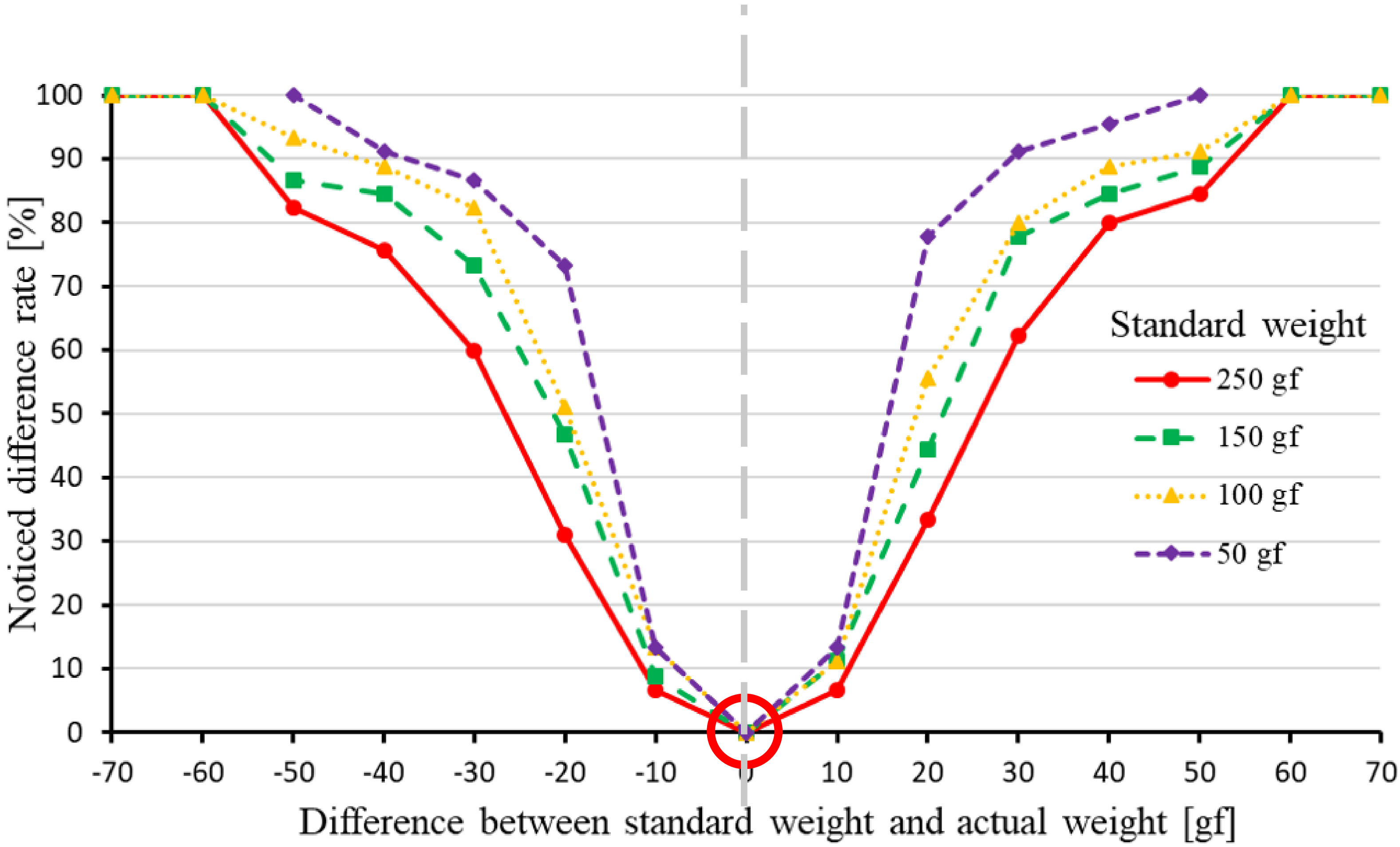
# Assessment Method (3/3)

- The standard weights are presented in a random order for each subject.

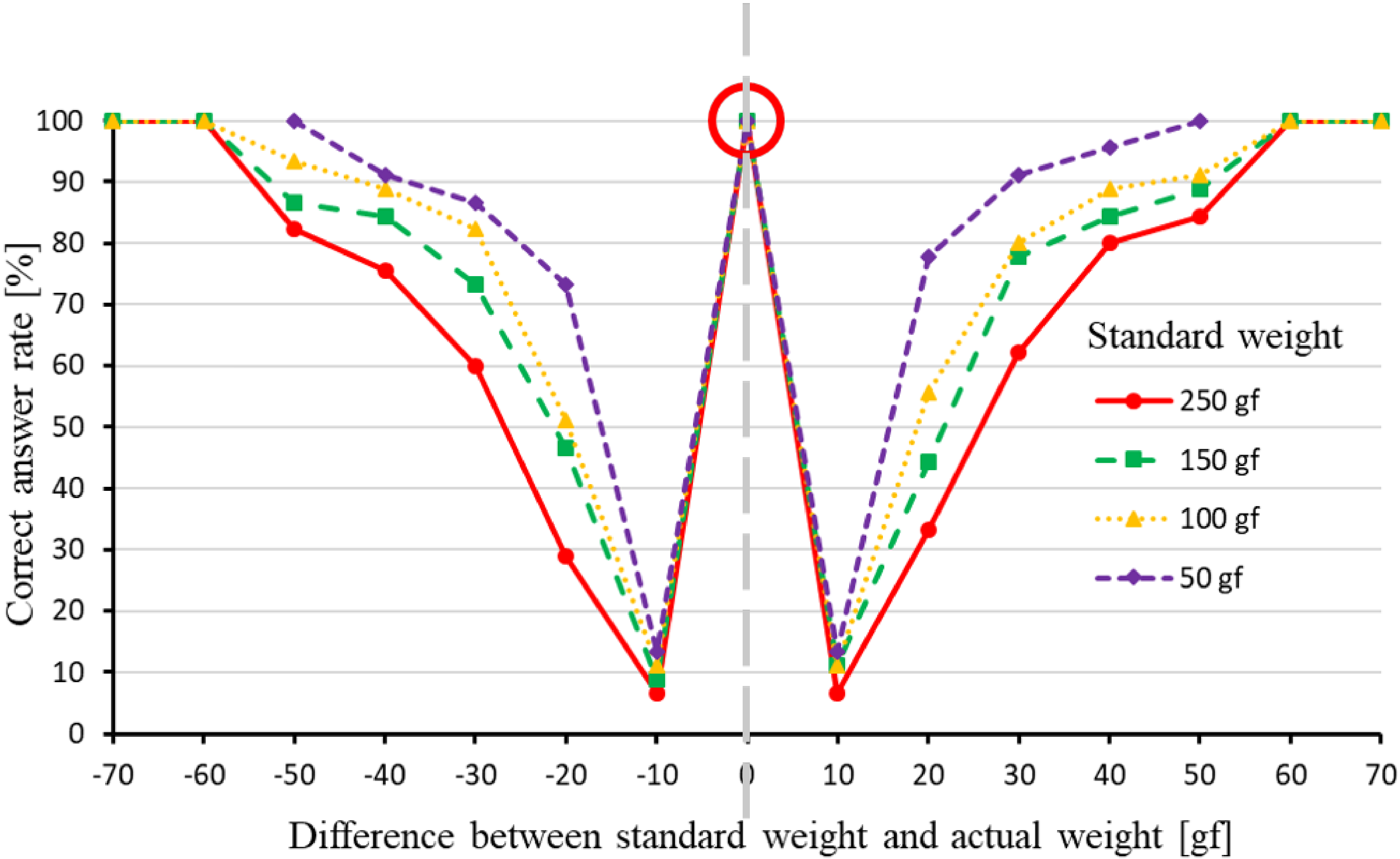
Correct answer of { Positive / Negative / 0 } is { “heavier” / “lighter” / “no change” }

| Correct answer of | is |
|---|---|
| Positive | “heavier” |
| Negative | “lighter” |
| 0 | “no change” |

# Assessment Results (1/4)



# Assessment Results (2/4)



# Assessment Results (3/4)

- The noticed difference rate and the correct answer rate are less than about 10% when the absolute difference is 10 gf.
- The subjects start to perceive the change of weight when the absolute difference exceeds about 20 gf.
- When the absolute difference is about 30 gf, the noticed difference rate and the correct answer rate exceeded about 70%.

As the standard weight becomes smaller, the noticed difference rate and the correct answer rate tend to increase.

# Assessment Results (4/4)

The shapes of the noticed difference rate and the correct answer rate look almost line-symmetrical.

- We conducted t-test for the noticed difference rate and the correct answer rate to examine whether there are significant differences between the positive and negative parts.
- We carried out the Tukey-Kramer method, which is used to perform multiple comparisons.

We confirmed that there is no difference between each positive part and the negative part in the perception of weight change.

# Conclusion

We carried out QoE assessment of human perception of weight in the remote robot system with force feedback.

- Can hardly perceive the weight change when the absolute difference is less than or equal to 10 gf.
- Start to perceive the change of weight when the absolute difference is about 20 gf.
- There is almost no difference between when the weight becomes lighter and when the weight becomes heavier if the weight change is the same in our assessment.

# Future Work

- Study the QoS control by using the results of this report, and investigate its effect.

- Investigate the influence of stabilization control on the weight perception.