Shoulder vibration feedback system for visually impaired people indoor navigation, and the study on the feedback strategy

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Background

3% visually impaired, 0.5% completely blind

Inclusive design and guide dogs are not available for everyone, especially in developing countries.

Personal accessibility devices are still needed for visually impaired people (VIP).

Problem & Goal

Indoor navigation for visually impaired people.

Elements

Sensing → Calculating → Feedback →

2D Image
Depth Image
Distance
Voice
Location
…

Sensor fusion
3D reconstruction
…
Decision making

Category: Vibro-Haptic feedback

Where to: On shoulder

Form: Backpack strap

How to: ? (The problem to be solved)

Goal

Clarification for “on shoulder”

1. Constrain: the movement of the body part must represent the movement of the person

    For collecting the body movement. The information is for a better feedback strategy

2. Prior test on vibration sensitivity

Part	Comment
Earlobe	Not sensitive. Distractive noise.
Back of the ear	Highly sensitive. Intense distractive and uncomfortable noise.
Shoulder	Highly sensitive on clavicle.
Upper arm	Not sensitive.
Belly	Sensitive.

Form

Method	Pros	Cons
Cane (robot)	Force feedback	Large
Cane (VR)	Force feedback	Large
Cane (vibration)	Simple	Limited information
Insole	Simulate road	Not sensitive
Wristband	Direction	Low accuracy
Two wristbands	Simple	Limited information
Jacket	Rich information	Large
Electrode	High accuracy	Dangerous
Belt	Rich information	Complex

Form is bonded with “where to”, and effects “**how to**”

How to provide the vibration feedback on shoulders?

Clarify the constrains → Via vibration, Two macro points (L/R shoulders)

↓

Clarify the **variables** → On space, On time, On energy, On strategy, From system

↓

Find out the **limitation** of human → **Hardware** above human limitation
Metrics for evaluating how human response

↓

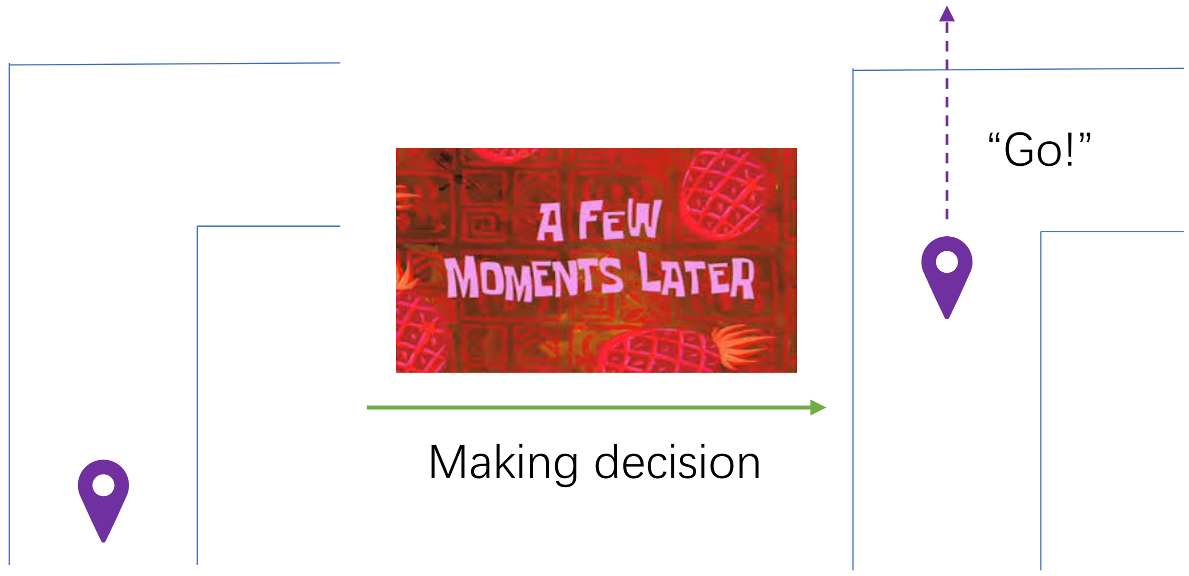
Build the feedback system accordingly

↓

Evaluate the solution → **Metrics** for comparing with other solutions

Clarify the variables

From the system - **Latency** from sensing to decision



Sensing

Feedback

*for demonstration, also has impact on rotation

The latency is related to

- The workload of algorithm
- The calculation power
- Communication latency

1/60 s: Limited by camera frame rate

10^2 ms: Cloud computing

10^3 ms: Edge computing

A variable for my tests

A constrain in solution

A problem to tackle

Clarify the variables

On strategy – Strategy for interpreting the instruction

Take advantage of locally information and calculation

From the feedback system

In the feedback system

Decision on next move
from calculation stage
based on info moments ago

Additional information
e.g. movement since last instruction
last instruction

Actual feedback

Feedback strategy
How to merge all the information
How to present the feedback

Clarify the variables

On time – Frequency of **Feedback adjustments**

On space – **Density** of vibration points

On energy – **Intensity** of the vibration

Strategy VS latency

Find the optimal combination inside this problem space

requires

Hardware above human limitation

Metrics to evaluate that

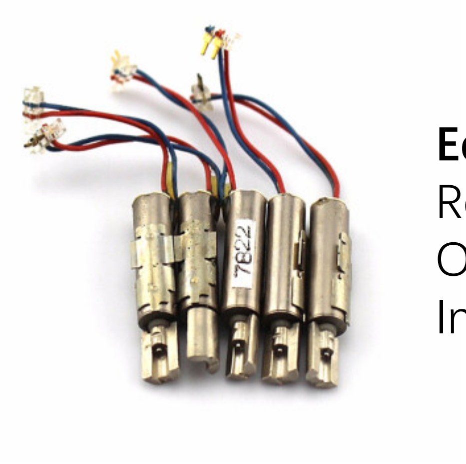
Hardware above human limitation

- **Hi-Fi shoulder vibration feedback.**

Intensity control every 6ms

12^{+}Bits intensity control 10^{3+} levels

Spatial density 1/(1*2cm)



Eccentric motors
Rotation -> vibration
On/Off
Inertia

Empowered by:

New actuator and new driven method

Closed loop control within feedback system

Linear actuators
Direct vibration
Analog intensity
Fast response

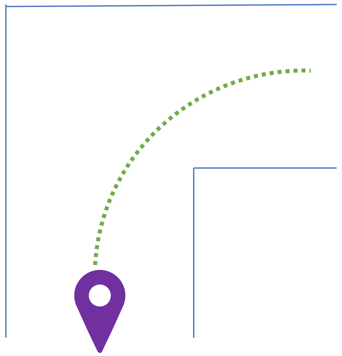
Metrics[1] for finding out the limitation

Task: **Orientation tracking**

Meaning

Set a dynamic orientation target
Guide the user rotate to it

Representing



Metrics

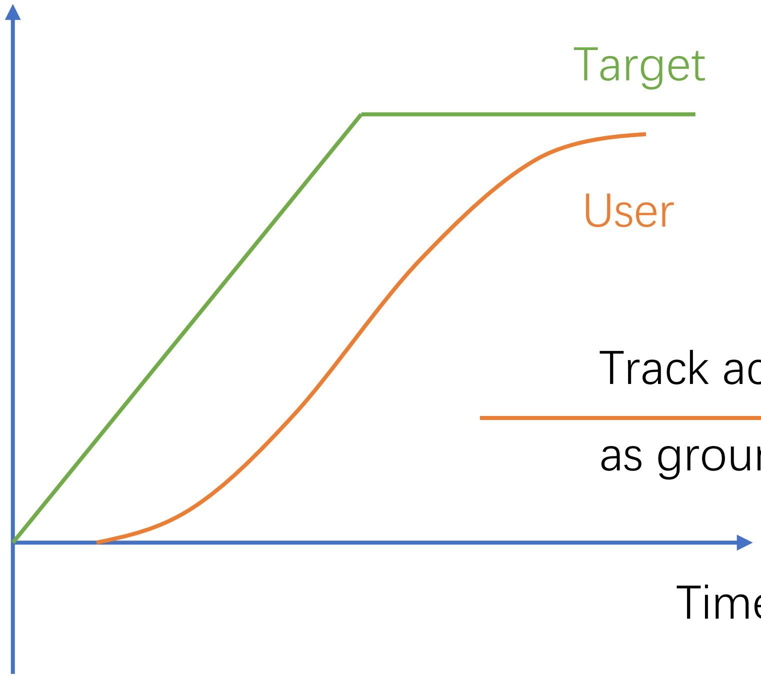
Standard deviation

Response time

Final accuracy

Over target count

...



Track accurately
as ground truth

Combinations of variables

Metrics to find human limitation

Optimal feedback system inside the problem space

Apply the optimal variables

Build the feedback system accordingly

Metrics to compare with other methods

System performance

Metrics^2 for comparison

Task: **Indoor navigation with simple scenario** $\xrightarrow{\text{Details}}$ **TBD**

Metrics ↓

Ground truth tracking ↓

CV system

Objective

Destination accuracy

Path accuracy

…

Subjective

Cognitive difficulty

Learning curve

…

Collaborated work with

Colleagues at Beijing working on general metrics

Other 2 GIX students with VIP navigation topics

Schedule

Time		Task
UW	Quarter 4	Further investigation. Build the haptic feedback **prototype** Design the haptic feedback **strategies** Design the tasks in **Metrics 1 & 2**
	Break (1 month)	Build the HTC Vive test platform for **Metrics 1**. Find the **optimal combination** with None-VIP participants Build the CV platform for **Metrics 2**. **Performance evaluation** with None-VIP participants
	Quarter 5	Iterate
Tsinghua		Rebuild the evaluation platforms. Fine tuning the optimal combination with VIP participants Performance evaluation with VIP participants **Paper writing**

Outcome

Combinations of variables

Metrics to find **human limitation**

Optimal feedback system inside the problem space

Contribution on

human factor study

Apply the optimal variables

Contribution on **technology**

Build the **feedback system** accordingly

Metrics to compare with other methods

System **performance**

Graduate or not

Contribution on **method**

Reference

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Thanks