Advanced 8
Human Welfare and Health Monitoring Technology

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1. Introduction
   - Background, Key points

2. Proposed method for evaluating distractions
   - Eye movement model, Model-based method

3. Experimental procedures
   - Primary task, Secondary task

4. Results
   - Influence on eye movement, Results of evaluation

5. Conclusion
• traffic accidents are not friendly to both of ourselves and natural environment

• 10% reduction of dead and injured in traffic accidents has 675 billion JPY per year economic effect
  (2004, cabinet office of Japanese government)

• one way in which the costs of driving can be reduced is by achieving more safety and fuel efficient driving.

• introduction of driver assistant systems can lead to fuel efficient and safe driving.
Importance for safety and fuel efficient driving

Display for ‘smart driving’

Secondary task
In-vehicle information system

Primary task
Manipulation & Quick detection

Information processing demand [bits/sec]

Attention to primary driving task

Estimate distractions

Control

Warning

Objective

To propose a method to quantitatively evaluate driver distractions caused by in-vehicle information system
• it is sometime required for drivers to have tolerable skills for maneuvering, or it is frequently short for drivers to have necessary information around the safety and the fuel efficiency.

• it may happen to drivers that they cannot control their behaviors from emotional or pathologic reasons while driving.

• **driver assistant systems** are expected, which are required to include human monitoring technologies for estimating physiological and mental status of drivers.
Key Points of our technology

The ideal variable for Human Monitoring

Non-intrusive Physical Responses
- Heart rate
- Respiratory rate
- Eye Fixation Gap
- Pupil size
- Vestibulo-Ocular Reflex

Mental Workload Driver’s Workload

- Low
- High

Any Linear Relationship (or monotonic relationship)

- quantitative measure
- dimensionless variable

involuntary eye movement
Model-based method
Key Point 1 - Reflexive eye movement -

- VOR (Vestibulo-Ocular Reflex)
- OKR (Optokinetic Reflex)

VOR (Vestibulo-Ocular Reflex) and OKR (Optokinetic Reflex) are mechanisms that help maintain visual stability during movement, especially under conditions of vibration or movement. The diagram illustrates how the human brain processes visual information and head movement to maintain gaze point stability.
**Key Point 1 - Reflexive eye movement -**

- **VOR (Vestibulo-Ocular Reflex)**
- **OKR (Optokinetic Reflex)**

**Diagram Description:**
- Head movement is connected to the human brain, which in turn is connected to the VOR (Vestibulo-Ocular Reflex) and OKR (Optokinetic Reflex).
- The visual scene interacts with the human brain, affecting the gaze point.
- Gaze stabilization under vibration of vehicle is demonstrated.
- Forward visual scene is shown with gaze point adjustment.
Key Point 1 - Reflexive eye movement -

- **VOR (Vestibulo-Ocular Reflex)**
  - Gaze stabilization under vibration of vehicle

- **OKR (Optokinetic Reflex)**
  - Predictable by the mathematical model
  - Involuntary movement Objective!
  - Quick reflex. In real-time!
Key Point 2 - Why VOR and OKR ? -

- **Cerebellum control**: Integration of the visual sensory system with the eye movement.
- Some information processing tasks have an influence on the dynamics of human VOR.
- The capability of reflexive eye movement comes down before the driver cannot perform driving task properly.

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![Diagram of Human brain, VOR, and OKR](image)
Key Point 3 - Model-based method -

Human brain

VOR

OKR

Head movement

Visual scene

Gaze point

Head movement & Visual scene

Model

Driver

Simulated output (= Normal action)

Detect the difference

Measured output

Normal reflex action
Model-Based Method

2 steps for proposed method

1. Identification of reflexive eye movement model
2. Comparing the measured output with the simulated output
Fig. 4. Eye movement model of the driver
Experimental Set-up

- **The rotation chair**
  - produces rolling and pitching motions
  - Amplitude: 0.1[deg]~3.0[deg]
  - Frequency: 0.8[Hz]~3.0[Hz]

- **Sampling parameters**
  - head position & rotation angle, rotation angle of eyeball, steering angle, rotation angle of chair
  - Sampling frequency: 50[Hz]

- **Subjects**
  - 5 men in their early twenties
Primary task

- **Tracking**
  - Manipulate the steering to track the target signal

- **Event detection**
  - Detect the change of color (red) as quickly as they can

Secondary task

- **Visual search**
  - Detect a particular alphabet from displayed alphabets
  - 12 different conditions
Secondary Task

Mental demand [bits/sec]

Amount of information driver must detect

I want to know the route and landmark and...

Visual demand [bits/sec]

Amount of information displayed on the HMI

I must detect A

I must detect A, B, C

I must detect A, B, C, D, E

Reaction time [sec]

0.3

0.4

0.5

0.6

0.7

0.8

0.9

1.0

1.2

0.3

0.4

0.5

0.6

0.7

0.8

0.9

1.0

1.2

Mental demand [bits/sec]

Visual demand [bits/sec]

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Secondary Task

Mental demand [bits/sec]

Amount of information driver must detect

I want to know the route and landmark and...

Visual demand [bits/sec]

Amount of information displayed on the HMI

Increasing the information processing demand

I want to know the route and landmark and…
Results

How distractions affect VOR and OKR?

1. No distractions
2. Get distracted
3. Get more distracted
Result 1: No Distractions

Simulated Model

Driver  

\( E(t) \)  

Measured

Simulated output

Measured output

Threshold

\( E(t) \)
Result 2: Get Distracted

Simulated Model

\[ E(t) \]

Driver

Measured

\[ E(t) \]

| Error |

\[ \text{Measured output} \]

\[ \text{Simulated output} \]

\[ \text{Threshold} \]
Result 3: Get More Distracted

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Evaluating The Distractions

Evaluation function

- Quantitatively evaluate the influence of distractions on human VOR and OKR

Evaluation function $J$

$$J = 100 \times \frac{\int_{\text{out}} E(t) \, dt}{\int_{\text{all}} E(t) \, dt} + \int_{\text{all}} E(t) \, dt$$

* all : all interval of tracking task (60[sec])
Results of Evaluation

Mental demand [bits/sec]
Amount of information driver must detect

Visual demand [bits/sec]
Amount of information displayed on the HMI

Influence of distractions on VOR and OKR

Large
Small
Results of Evaluation

Subject B

Subject C

Subject D

Subject E
Discussions

Driver Assistant system

state estimator of driver

car

dynamic environment

receptors

adaptation

sensors

adaptation

Human (driver)
Conclusion

As the imposed mental workload increased, the error index of VOR response increased.

A. This indicates that mental workloads can be quantified using VOR measurement

- possibility to overcome the variation in individuals
- can detect such short-term changes
- can eliminate the effect of voluntary eye-movements

B. The proposed method has the following advantages when applied to quantifying mental workloads.

B1. **Non-obtrusive** to human body
B2. **Non-intrusive** to the task
B3. **Objective** measurement
B4. Measurable in **real-time**
B5. **Vehicle vibration** can be utilized.
B6 Extension to **Optokinetic situations**

The method can be used for drivers monitoring.
Eye Movement Model VOR

**VOR model**

- Modeling the dynamics of VOR from head movement to eye movement
- Identify 4 parameters in VOR model for a particular person

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**Consist of the VOR and OKRVOR and OKR part**

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*D.M. Merfeld, 2001*
Motions of eyeball

Head position & rotation

Angular velocity

Neural integrator

Final common path

Extraocular muscle

VOR

Velocity storage

Final common path

Leaky integrator

\[ T_0 = 6.0 \]

\[ \frac{1}{T_0 s + 1} \]

\[ k_{vs} \]

\[ \frac{T_n}{T_n s + 1} \]

\[ k_i \]

\[ \frac{T_n}{T_n s + 1} \]

\[ k_p \]

\[ \frac{1/k}{T_v s + 1} \]

\[ k = 4.0 \]

\[ T_v = 0.24 \]
OKR model

- Modeling the dynamics of OKR which compensates the retinal velocity error
- Identify 2 parameters in the model

*G. Schweigart, 1999
Controller
sensory

State Estimator

Controller
motor

compensation
stimulation
obstacle
detection
heart
rate
aspiration
eye
movement

state
variables
of
vehicle

stimulation
automation

maneuvering
braking

vibration
posture
control

assistance
alarm
disillusionize

perfume
fever
light
pressure
oxygen

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Key Point

3. Model-based method

- Detect the influence of distractions on VOR and OKR by comparing with the simulated reference output
- Carry out in real time
- Be able to estimate driver distractions while driving in real time

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**Diagram:**

- Head movement & Visual scene
  - Model
    - Simulated output
    - Detect the difference
  - Driver
    - Measured output

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Details of experiment

**Tracking**
- Manipulate the steering to track the target signal for 60 [sec]
- Target signal colored noise that frequency band is between 0.03 [Hz] and 0.5 [Hz]

**Event detection**
- Detect the change of color (red) as quickly as they can
- The color is change blue or red or yellow once in a 20 [sec]

**Visual search**
- Displayed once every 3 [sec] to 6 [sec]
- Displayed for 1 [sec] which is the instance permitted to look navigation while driving.
Result 1: No Distractions

[Diagram showing a model, a simulated output, a measured output, and the error calculation process (E(t))]

Measured output
Simulated output

E(t)
Threshold

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Result 2: Get Distracted

- Simulated
- Measured
- Error

Model

Driver

E(t)

Measured output vs. Simulated output

E(t) vs. Threshold

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Result 3: Get More Distracted

[Diagram showing a simulated and measured model of a driver system, with error calculations and threshold monitoring.

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Result

How distractions affect VOR and OKR?

1. No distractions  
   (without secondary task)

2. With distractions  
   (with secondary task)
Results With Distractions

Model

Driver

Simulated

Measured

$E(t)$

$\text{Error}$

A, B, C

Simulated output

Measured output

Horizontal angle

Threshold

Vertical angle

Threshold
Results With Distractions

Model ① Simulated

Driver ② Measured

| Error |

③ $E(t)$

A, B, C, D, E

- Measured output
- Simulated output
- $E(t)$
- Threshold

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Amount of Information

1 alphabet = 2.62 [bits]

Mental demand [bits/sec]

Calculated by

\[ U = - \sum P_i \log_2 P_i \]

\[ P_i = \frac{2}{3}, \frac{2}{9}, \frac{2}{15} \]

Visual demand [bits/sec]

Mean value of an alphabet
Identification of VOR model

VOR model

- Modeling the dynamics of VOR from head movement to eye movement
- Identify 4 parameters in VOR model for a particular person

Method for identification

- Using Genetic Algorithm
- To minimize the error between measured output and model output

* D.M. Merfeld, 2001

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VOR parameter

VOR model

- Modeling the dynamics of VOR from head movement to eye movement
- Identify 4 parameters in VOR model for a particular person

Individual parameter

- Different among individuals
- Identified for a particular person

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<td>-6.40</td>
<td>0.10</td>
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<td>25.50</td>
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</tbody>
</table>

*D.M. Merfeld, 2001*
Detect from the difference of velocity between the two
VOR-OKR Interaction

- VOR is dominant in our experiment

- Visual stimuli that produces OKR is not generated

In the real world, visual scene moves relative to driver’s head position
Threshold Level

- The data when the subject does not get distracted

The predicted error is:

Average = 0
Variance = \( \sigma \)

**Normal distribution**

Threshold level is the double standard deviation

(Which include 95.44% of noise when subject doesn’t distracted)
FFT Analysis

Without distractions

- Decrease the value of coherence
- Distractions affect the dynamics of VOR

With distractions
Results of Evaluation

displayed 16 items
displayed 9 items
displayed 4 items
displayed 1 item

Amount of information subjects must detect [bits]

60.00 75.00 90.00 100.0

0.39 1.45 10.48

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VOR Model

Linear acceleration

\[ \int g \times \omega dt \]

Angular velocity

\[ \omega \]

\[ \alpha \times \dot{\omega} \]

\[ \theta_{\text{error}} \]

\[ \hat{\alpha} \]

\[ \int S_{oto} \]

\[ S_{scs} \]

\[ S_{oto} \]

\[ \hat{S}_{oto} \]

\[ k_a \]

\[ k_f \]

\[ k_{fw} \]

\[ k_w \]

\[ \hat{S}_{scs} \]

\[ \int g \times \omega dt \]

\[ \hat{\alpha} \]

\[ \int \hat{a} dt \]

\[ 1/\tau_v \]

\[ \hat{v} \times \hat{d} \]

High Pass Filter

Eye movement

Input to sensor

Internal processing

Eye movement

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Influence of distractions on eye movement increase!!

The tracking performance does not come down!!

Increase mental demand