Images in mind – Design metaphor and method to classify driver distraction in critical situations
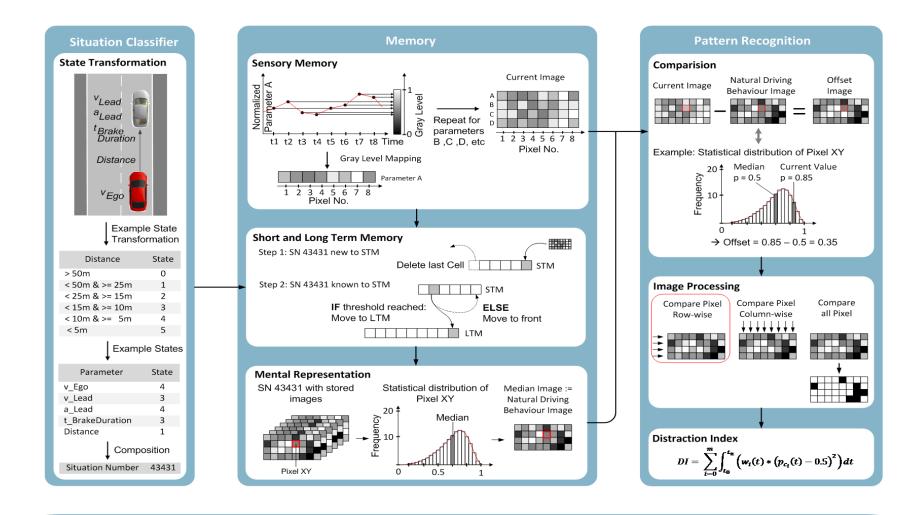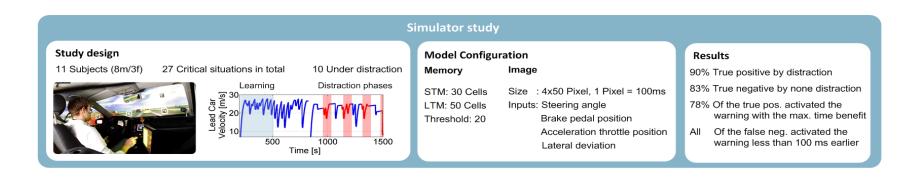
Bilder im Kopf – Designmetapher und Methode zur Klassifikation von Fahrerablenkung in kritischen Situationen

We are presenting a driver model developed within the EU-project interactIVe which classifies visual distraction based on the detection of abnormal driving behavior. The model forwards the information to a Collision Mitigation System and activates an acoustic warning in case of distraction up to 300 ms earlier.

Since the model requires information regarding normal driving behavior to do this, we introduced a design metaphor, focused on using human memory and its ability to construct mental representations. Based on the idea of interpreting multivariate time series as gray-level images, we adapted the concept of mental images for learning situation-based normal behavior.

The model transformed the property of long-term memory to store, interfere and forget prototypes of mental images. During driving, we compared the prototypical images stored with the current image to obtain a distraction index. If this index exceeded a certain threshold, the warning was actuated. The driver model was evaluated in a simulator study where the system improvement could be shown.

Situation Classifier

State Transformation

v_{Lead}
a_{Lead}
$t_{Brake\ Duration}$

Distance

v_{Ego}

Example State Transformation

Distance	State
> 50m	0
< 50m & >= 25m	1
< 25m & >= 15m	2
< 15m & >= 10m	3
< 10m & >= 5m	4
< 5m	5

Example States

Parameter	State
v_Ego	4
v_Lead	3
a_Lead	4
t_BrakeDuration	3
Distance	1

Composition

Situation Number	43431

Memory

Sensory Memory

Normalized Parameter A
Gray Level
t1 t2 t3 t4 t5 t6 t7 t8 Time

Repeat for parameters B, C, D, etc

Current Image
A B C D
1 2 3 4 5 6 7 8
Pixel No.

Gray Level Mapping
1 2 3 4 5 6 7 8
Pixel No.
Parameter A

Short and Long Term Memory

Step 1: SN 43431 new to STM
Delete last Cell — STM

Step 2: SN 43431 known to STM
STM

IF threshold reached: Move to LTM
ELSE Move to front

LTM

Mental Representation

SN 43431 with stored images

Statistical distribution of Pixel XY
Median
Frequency
0 0.5 1

Median Image := Natural Driving Behaviour Image

Pixel XY

Pattern Recognition

Comparision

Current Image − Natural Driving Behaviour Image = Offset Image

Example: Statistical distribution of Pixel XY

Median p = 0.5
Current Value p = 0.85
Frequency
0 1

→ Offset = 0.85 − 0.5 = 0.35

Image Processing

Compare Pixel Row-wise

Compare Pixel Column-wise

Compare all Pixel

Distraction Index

$$DI = \sum_{i=0}^{m} \int_{t_0}^{t_n} \left(w_i(t) * \left(p_{c_i}(t) - 0.5 \right)^2 \right) dt$$

Simulator study

Study design

11 Subjects (8m/3f) 27 Critical situations in total 10 Under distraction

Learning Distraction phases
Lead Car Velocity [m/s]
500 1000 1500
Time [s]

Model Configuration

Memory

STM: 30 Cells
LTM: 50 Cells
Threshold: 20

Image

Size : 4x50 Pixel, 1 Pixel = 100ms
Inputs: Steering angle
Brake pedal position
Acceleration throttle position
Lateral deviation

Results

90% True positive by distraction

83% True negative by none distraction

78% Of the true pos. activated the warning with the max. time benefit

All Of the false neg. activated the warning less than 100 ms earlier

Deutsches Zentrum für Luft- und Raumfahrt

Institut für Verkehrssystemtechnik
Lilienthalplatz 7
38108 Braunschweig

Dipl. Math. Stefan Griesche
Telefon: 0531-295-3522
Email: Stefan.Griesche@dlr.de