Information Fusion (IFU)

Summer Semester 2021

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Name: ____________________

Registration number: ____________________

Remarks

- You have 120 Minutes to reupload your exam to the eAssessment. Please save enough time for the uploading.
- Lecture slides, exercises, and your personal notes are allowed as aids.
- A written answer is expected in full sentences. Writing down keywords is **not** sufficient.
- **Do not copy text from any source into the answer fields.** Always give your answers in your own words. Copied text leads to a failed exam automatically.
- Total points: 100; passed with at least 40 points.

Points	< 40	$[40, 45.5]$	$[46, 51.5]$	$[52, 57.5]$	$[58, 63.5]$	$[64, 69.5]$
Grade	5.0	4.0	3.7	3.3	3.0	2.7

Points	$[70, 75.5]$	$[76, 81.5]$	$[82, 87.5]$	$[88, 93.5]$	$[94, 100]$
Grade	2.3	2.0	1.7	1.3	1.0

1. Fusion and Conflict in Dempster-Shafer Theory (35 P.)

Advanced driver-assistance systems, such as the adaptive cruise control (ACC) and the collision avoidance system (CAS), allow vehicles to be operated semi-autonomously. Both the ACC and the CAS rely on distance measurements to the vehicle driving in front (cf. Fig. 1). The ACC is only allowed to be active if the front vehicle is in a safe distance. The CAS emergency brakes if the front vehicle is closer than a critical distance. Safe and critical distance are dependent on the speed of the operated vehicle.

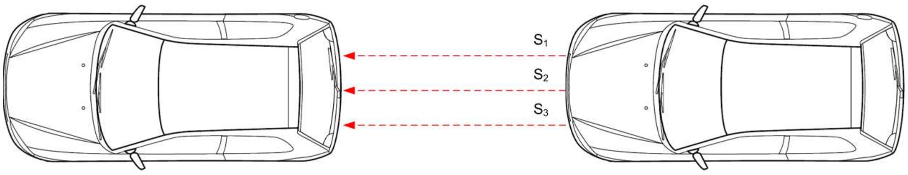

Figure 1: Sketch of a car distance measurement

Distance measurement is executed by three independent sensors: a radar S_1, a lidar S_2, and a camera-based sensor S_3. Each sensor returns three signals „S = safe distance“, „U = unsafe distance“, and „C = below critical distance“, that is, $\Omega = \{\mathrm{S}, \mathrm{U}, \mathrm{C}\}$. If there are no signal outputs, it is assumed that a vehicle in front could not be detected. The measurements are defined via their basic belief assignments $m_i(\circ) \in [0, 1]$, $i \in \{1, 2, 3\}$.

You may use the following symbols for an easier use within this PDF:

- Omega := Ω,
- emptyset := $\varnothing$, and
- you may write indices with an underscore, for example: $m\_1 := m_1$ or $k\_c := k_c$.

1.1 Define the power set of the frame of discernment. /4

1.2 While driving at a speed of $90\,\mathrm{km\,h^{-1}}$ the sensors output the following basic belief assignments:

	$m_i(\mathrm{S})$	$m_i(\mathrm{U})$	$m_i(\mathrm{C})$	$m_i(\{\mathrm{U}, \mathrm{C}\})$	$m_i(\Omega)$
S_1	0.6	0	0	0.4	0
S_2	0.3	0.1	0	0	0.6
S_3	0.5	0.4	0	0	0.1

All elements of the power set, which are not listed, have a mass of 0.

1.2.1 Interpret the evidential masses $m_1(\{\mathrm{U}, \mathrm{C}\}) = 0.4$ and $m_2(\Omega) = 0.6$. /5

1.2.2 Apply DEMPSTER's rule of combination for the sensors S_1 and S_2. Calculate the conflict factor k_c and the joined masses $m_{12}(\circ)$. Interpret your result. /13

1.2.3 Now include the sensor S_3. Calculate the conflict factor k_c and the joined masses $m_{123}(\circ)$. Interpret your result. /13

2. Fusion in Possibility Theory (30 P.)

DUBOIS and PRADE proposed the following fusion equation for possibility values $\pi \in [0, 1]$:

$$h(\pi_1, \pi_2) = (1 - k_c) \cdot \max\left(\frac{\min(\pi_1, \pi_2)}{1 - k_c}, \min(1 - k_c, \max(\pi_1, \pi_2))\right),$$
$$k_c = f(\pi_1, \pi_2) \in [0, 1[\ .$$

2.1 The fusion operator h has an optimistic and a pessimistic mode. In the following we look into the pessimistic case in which it is assumed that there is maximum conflict between sources. Which of the following statements is true in the pessimistic case, that is, if $k_c = 1 - \epsilon$, $\epsilon > 0$, $\epsilon \ll 1$? /10

A. $h = 0$.
B. $h = 1$.
C. $h \to \infty$.
D. $h \to -\infty$.
E. $h = \min(\pi_1, \pi_2)$.
F. $h = \max(\pi_1, \pi_2)$.
G. h converts into the arithmetic means operator.
H. h converts into the generalised means operator.
I. h converts into the harmonic means operator.
J. The *orness* of h becomes 0.
K. The *andness* of h becomes 1.
L. The *andness* and *orness* of h becomes 0.5.
M. h becomes undefined.
N. None of the above statements is true.

2.2 Which of the following statements is true regarding the *boundedness* of h? /5

A. h is bounded because $h \leq \max(\pi_1, \pi_2)$.
B. h is bounded because $\min(\pi_1, \pi_2) \leq h \leq \max(\pi_1, \pi_2)$.
C. h is bounded because $h(\pi_{a_1}, \pi_{a_2}) \geq h(\pi_{b_1}, \pi_{b_2})$ if $\pi_{a_i} \geq \pi_{b_i}$ $\forall i \in \{1, 2\}$.
D. h is bounded only if $\pi = \pi_i$ $\forall i \in \{1, 2\}$.
E. h is not bounded because $\min(\pi_1, \pi_2) \leq h$.
F. h is not bounded because it is possible that $h > 1$.
G. h is not bounded because $h(\pi_{a_1}, \pi_{a_2})$ is not always greater than $h(\pi_{b_1}, \pi_{b_2})$ if $\pi_{a_i} \geq \pi_{b_i}$ $\forall i \in \{1, 2, \ldots, n\}$.
H. None of the above statements is true.

2.3 Which of the following statements is true regarding the *idempotency* of h? /5

A. h is idempotent because $h \leq \max(\pi_1, \pi_2)$.

B. h is idempotent because $h(\pi_1, \pi_2) = h\big(\pi_{r(1)}, \pi_{r(2)}, \dots, \pi_{r(n)}\big)$ for any permutation r on $\mathbb{N}_n$.

C. h is idempotent because $\min(\pi_1, \pi_2) = \max(\pi_1, \pi_2) = \pi$ if $\pi = \pi_i \; \forall i \in \{1, 2\}$.

D. h is idempotent only if $k_{\mathrm{c}} = 0$.

E. h is idempotent only if $k_{\mathrm{c}} \to 1$.

F. h is not idempotent if $\pi_1 = \pi_2$.

G. h is not idempotent if $\pi_1 \neq \pi_2$.

H. h is not idempotent because $h \leq \max(\pi_1, \pi_2)$.

I. h is not idempotent because $\min(\pi_1, \pi_2) \leq h$.

J. None of the above statements is true.

2.4 Possibility distributions are closely related to fuzzy membership functions. Would it make sense to apply h to fuzzy memberships ($\mu \in [0, 1]$)? If your answer is yes, what would need to be considered in an application on memberships? If your answer is no, why do you think that it is not sensible to do so? Reason your statements. /10

3. Bayes Reasoning (35 P.)

Banknote authentification systems (BAS) play an important role in fighting money counterfeiters. Assume a BAS is installed in a cash register at a supermarket. Banknotes are eyed by the cashier and then only tested by the BAS if the cashier is suspicious. From previous experience it is known that – even then – the probability of a counterfeit is low. It is estimated to be 0.02. Furthermore it is known that the BAS has a sensitivity of 0.987 and a false positive rate of 0.009.

Remark for this online-exam: You may type equations with fractions as follows $P(A) = (B + C)/(D \cdot E + F)$.

3.1 Define all probabilities necessary for the banknote authentification using Bayes' theorem. /5

3.2 Calculate the total probability. /10

3.3 Calculate the probability of having a counterfeit banknote given a positive test using Bayes' theorem. /10

3.4 Is this approach still correct and applicable if the same BAS is installed in an automated teller machine (ATM)? Why is this the case or why not? /10