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Generation of Criticality Index For Functional Scenarios Related to the Driving Automation Testing

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Motivation

- Need to regularly test new functionalities on CAV and set up pre-certification).(processes, including test phases.
- Multiple test protocols exist in the literature [3]. We get interested in a scenario-based).(protocol [3], which are usually split into 3 steps:
 - **Step 1:** Generation/Extraction of any feasible scenario).(



Functional scenarios (Sf) include operating scenarios on a semantic level. [1] Logical scenarios (Sl) include operating scenarios on a state space level. [1] Concrete scenarios (Sc) distinctly depict operating scenarios on a state space level.

- **Step 2:** Application of a sampling process to select a set of concrete scenarios).(
- **Step 3:** Evaluation of CAV performance
- This paper proposes an extension of the protocol to include a prior assessment of).(scenario criticality with the purpose of guiding the sampling process of tested scenarios.

Methodology

ODD

- The prior criticality assessment process is split into 4 steps.).(
- Step 1 : Generation of Functional Scenarios (Sf) from an ontology based on 5).(layers.
 - <u>Main specificity</u>: Introduction of stochasticity in the ontology: the trajectories of the obstacle-vehicles in the surrounding of the EGO vehicle (under test) are not exhaustively described, but formulated according to macroscopic traffic indicators (e.g. traffic demand) with random seeds.
 - Any Functional Scenario ($S_{f_i}^{ontology}$) is featured by a set of words (β_{w_n})

 $\forall i \in [1, q] \quad S_{f_i}^{ontology} = (\beta_{w_1} \ \beta_{w_2} \dots \ \beta_{w_n}) \qquad \forall j \in [1, n] \quad \beta_{w_n} \in \{0, 1\}$

- **Step 2 : Estimation of criticality indicators from field test observations**).(
 - Assigning the appropriate set of words (*i.e.* ontology's attributes) defining a).(functional scenario to any concrete scenario instantiated on the field and resulting in data collection (use of LevelxData).
 - Computing the frequency distribution over a criticality indicator (here, Time To).(Collision – TTC) for any available functional scenario with field observations.

Step 4 : Generation of *a priori* criticality indicator for any Functional Scenario, defined by a set of words / ontology's attributes. Thanks to the least mean square method, the process is adjusting a combination of the words generating the K latent topics with the ones associated to the Functional Scenario.

Definition

$$\forall i \in [1, q] \quad S_{f_i}^{new} = \sum_{k=1}^{K} topic^k * \alpha_k \iff \begin{pmatrix} \beta_{w_1}^i \\ \beta_{w_2}^i \\ \dots \\ \beta_{w_n}^n \end{pmatrix} = \begin{pmatrix} p_{w_1}^1 & \cdots & p_{w_1}^K \\ \vdots & \ddots & \vdots \\ p_{w_n}^1 & \cdots & p_{w_n}^K \end{pmatrix} * \begin{pmatrix} \alpha_1 \\ \alpha_2 \\ \dots \\ \alpha_K \end{pmatrix}$$

$$\boldsymbol{\beta} = \boldsymbol{P} \ast \boldsymbol{\alpha} \Leftrightarrow \parallel \boldsymbol{P} \ast \boldsymbol{\alpha} - \boldsymbol{\beta} \parallel^2 = \boldsymbol{0}$$



$$\forall i \in [1, q] \quad S_{f_i}^{safety} = \begin{pmatrix} d^{safety}(S_{c_1}) \\ d^{safety}(S_{c_2}) \\ \dots \\ d^{safety}(S_{c_{nb_i}}) \end{pmatrix}$$

Step 3 : Extraction of Underlying and Latent Relationship between ontology).(attributes and Criticality Index of Functional Scenario thanks to the Latent Dirichlet Allocation (LDA) [2] clustering method.

$$\forall k \in [1, K] \ topic_k^{ontology} = (p_{w_1}^k \ p_{w_2}^k \dots \ p_{w_n}^k)$$
$$p_{w_j}^k \in [0, 1] \ p_{w_j}^k = \sum_{i \in [1, q]} \theta_k^{(i)} * \frac{\beta_{w_j}^{(i)}}{\sum_{s \in [1, q]} \beta_{w_j}^{(s)}}$$

topic 2

📕 topic 🕻

Each latent topic resulting from the LDA is featured by a frequency distribution over the words / ontology's attributes and is supposed to be a generator for any S_{f} .



Conclusion

- Difficulty in accurately reconstructing profiles since raw profiles are noisy, while typical profiles are).(smooth. It strongly affects the Key Performance Indicators under consideration.
- Opportunity operate with new databases to extend the set of Sf and ontology's attributes covered.



[1] Menzel, T., G. Bagschik, and M. Maurer, Scenarios for development, test and validation of automated vehicles. In 2018 IEEE Intelligent Vehicles Symposium (IV), IEEE, 2018, pp. 1821–1827 [2] Blei, D. M., A. Y. Ng, and M. I. Jordan, Latent dirichlet allocation. Journal of machine Learning research, Vol. 3, No. Jan, 2003, pp. 993–1022

[3] Riedmaier, S., T. Ponn, D. Ludwig, B. Schick, and F. Diermeyer, Survey on Scenario Based Safety Assessment of Automated Vehicles. IEEE Access, Vol. 8, 2020, pp. 87456-87477, conference Name: IEEE Access.