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Modelling the Safety Tolerance Zone: Recommendations from the i-DREAMS project

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The i-DREAMS project

- 13 Project partners:
  - National Technical University of Athens

    Universiteit Hasselt, Loughborough University, Technische Universität München, Kuratorium für Verkehrssicherheit, Delft University of Technology, University of Maribor, OSeven Telematics, DriveSimSolutions, CardioID Technologies, European Transport Safety Council, POLIS Network, Barraqueiro Transportes S.A.

- Duration of the project:
  - 36 months (May 2019 – May 2022)

- Framework Program:
  - Horizon 2020 - The EU Union Framework Programme for Research and Innovation - Mobility for Growth

Introduction

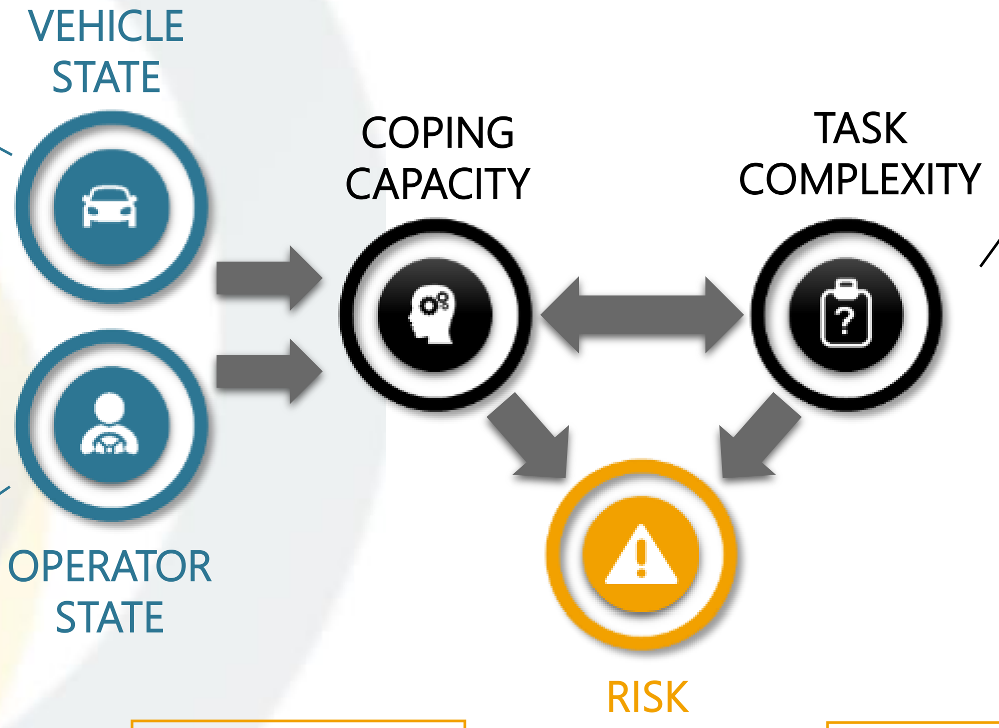
Definition, development, testing and validation of a context-aware 'Safety Tolerance Zone':

- raw time-series sensor data and driver background data are transformed into indicators
- operator capacity and task complexity variables are used for a multi-dimensional assessment of driving context and crash risk prediction
- appropriate driver comfort related interventions take place in real-time to recall driver back into a safe area if needed and guidance is given post-trip to improve driving behavior

Concept Overview

- Technical specifications
- Actuators & admitted actions
- Vehicle current status

- Mental state
- Behaviour
- Competencies
- Personality
- Soc. Dem. Profile
- Health status



- Road layout
- Time & location
- Traffic
- Weather

Danger phase events

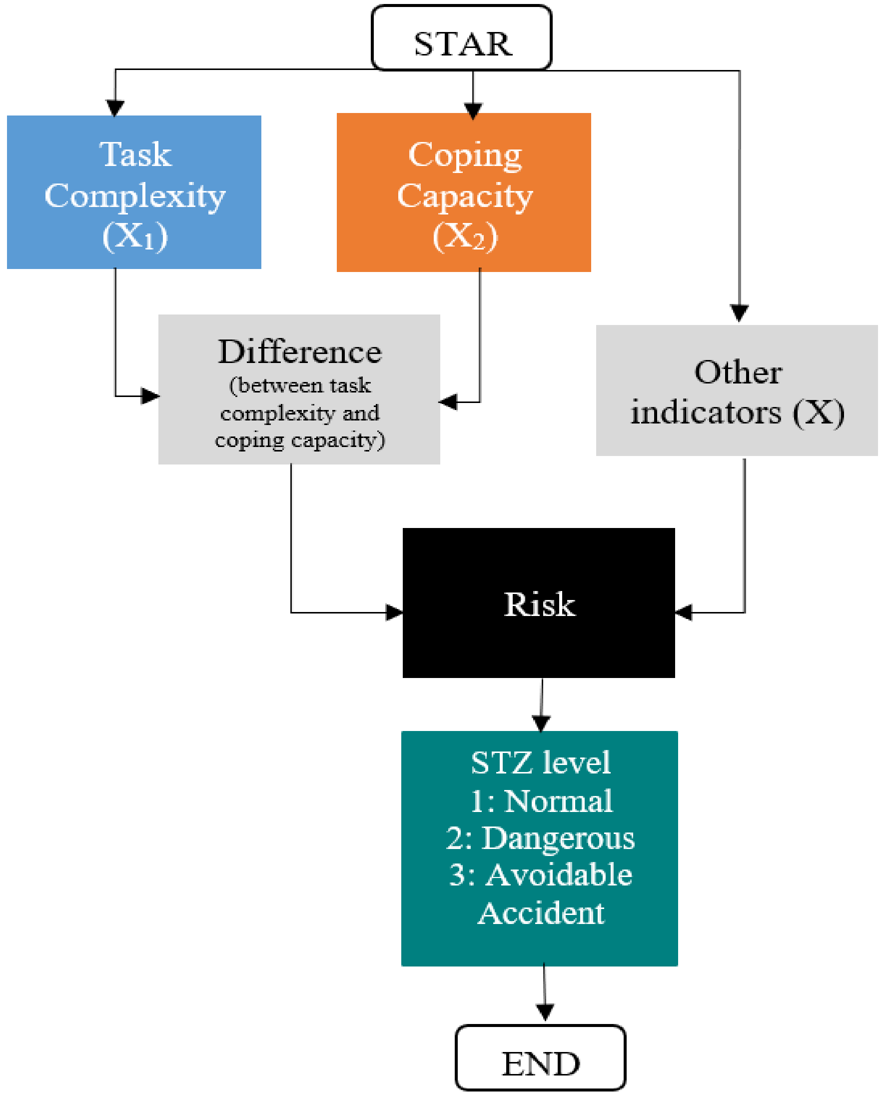
Avoidable accident events

Background

- Predicting driving behavior by employing mathematical driver models, obtained directly from the observed driving-behavior data, has gained much attention
- Different models and methodologies which include the relationship and the interaction between task complexity and coping capacity were examined
- The most suitable models, able to estimate driving behavior and crash risk were identified
    - Bayesian Neural Networks
    - Clustering Models
    - Fuzzy Logic Models
    - Hybrid Input Output Automaton
    - Long Short-Term Memory Models

Methodological Overview

- It is hypothesized that a situation is risky if the level of task complexity is different from the level of coping capacity
- In order to identify risk, the level of task complexity and the level of coping capacity need to be predicted and compared
- The hypothesis forms a real-time multi-level classification problem, where the dependent variable takes the form of a category representing the difference of task complexity and coping capacity
- Task complexity variables (X_1) and coping capacity variables (X_2) can be used to identify individual levels of coping capacity and task complexity and can also be supplemented by other indicators in order to predict Y



Examined Variables

In order to model the concept of the i-DREAMS project, several parameters were examined:

Dependent variable:

- **STZ_Speed** (normal phase:0, dangerous phase: 1, avoidable accident phase: 2)

Independent variables:

- **Headway** (time headway to vehicle ahead in same lane – sec)
- **TTC** (time to collision with vehicle ahead – sec)
- **Distance travelled** (distance driving – m)
- **HandsOnEvent** (whether hands are on the steering wheel – none/both)
- **FatigueEvent** (KSS score – values: -1, 35, 39, **32 value not recorded*)
- **ME_ForwardCollisionWarning** (whether forward collision warning is active – true/false
- **ME_LaneDepartureWarningActive** (whether LDW is active – true/false)

Correlation of Variables

➢ No strong correlation among the independent variables was identified

	Headway	TTC	Distance.travelled	HandsOnEvent	FatigueEvent	ME_ForwardCollision Warning	ME_LaneDeparture WarningActive
Headway	1,000	0,000	-0,081	-0,098	-0,124	-0,005	-0,024
TTC	0,000	1,000	0,000	-0,010	-0,078	0,001	-0,007
Distance.travelled	-0,081	0,000	1,000	0,024	0,097	0,004	0,000
HandsOnEvent	-0,098	-0,010	0,024	1,000			
FatigueEvent	-0,124	-0,078	0,097		1,000		
ME_ForwardCollision Warning	-0,005	0,001	0,004			1,000	-0,008
ME_LaneDeparture WarningActive	-0,024	-0,007	0,000			-0,008	1,000

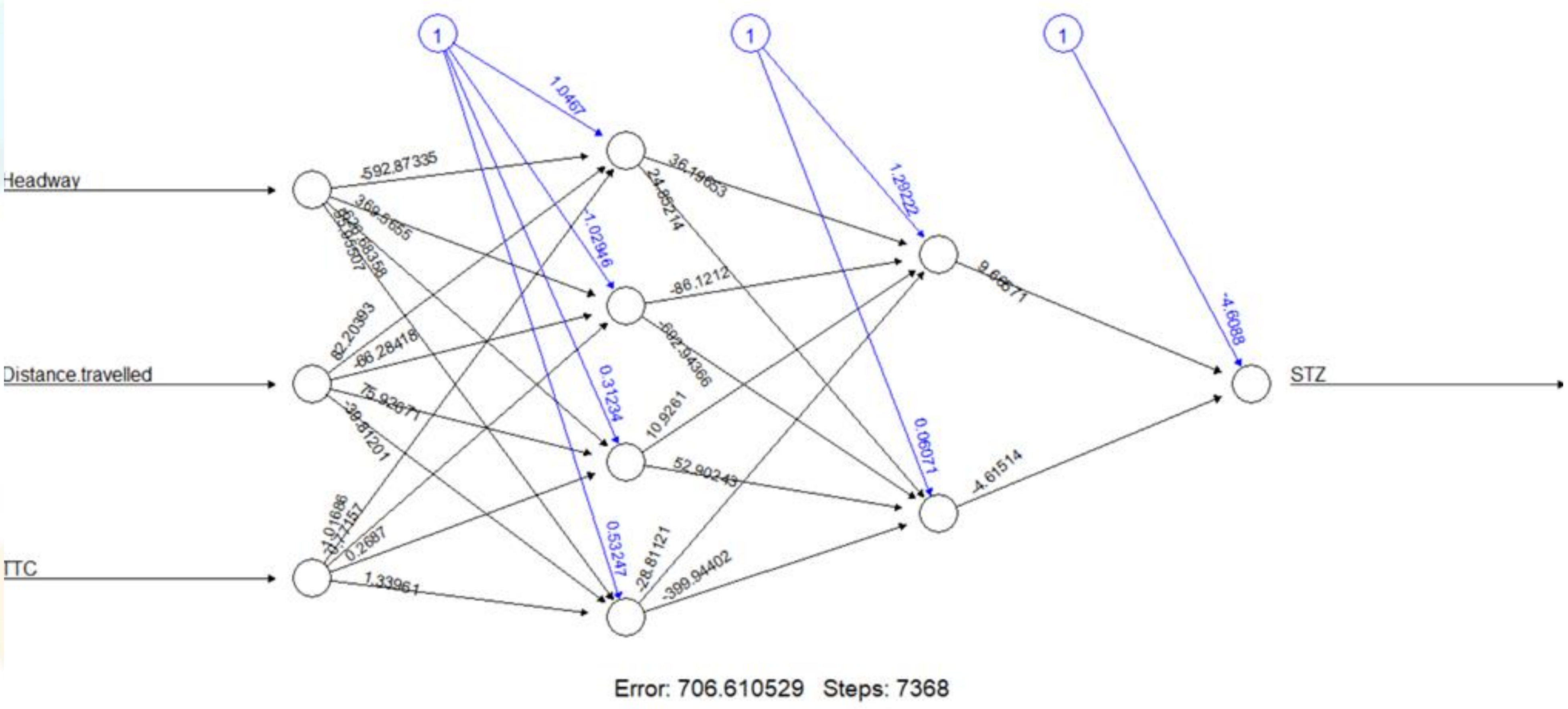
Feature Importance

- A feature importance algorithm extracted from XGBoost was used to evaluate the significance of variables on forecasting Safety Tolerance Zone (STZ)
- Headway, distance travelled and TTC were the most important factors of all examined indicators
- The parameters of forward collision warning and lane departure warning active were less significant

A/A	Variables	Importance
1	Headway	0.4628857977881
2	Distance.travelled	0.3689770387145
3	TTC	0.1681097785940
4	ME_ForwardCollisionWarning	0.0000203474815
5	ME_LaneDepartureWarningActive	0.0000004199277

Neural Networks

- Three neurons in the input layer (i.e., headway, distance.travelled and TTC)
- One neuron in the output layer (i.e., STZ)



Assessment of Classification Model

- Positive class refers to the Dangerous phase
- Negative class refers to the Normal phase
- No instances for Avoidable Accident Phase were detected

Actual (True) Class	Predicted Class	
	0	1
0	True Negative (TN)	False Positive (FP)
1	False Negative (FN)	True Positive (TP)

Actual (True) Class	Predicted Class	
	0	1
0	157	797
1	0	1546

Accuracy	Precision	Recall	Specificity	f1-score	G-Means	FP Rate
0,68	0,66	1,00	0,16	0,80	0,81	0,84

Conclusions

- The most prominent approaches, dealing with driver behavior and collision risk modelling in real-time, were found to be Dynamic Bayesian Networks and Long Short-Term Memory networks
- Suitable for prediction of continuous indicators of risk (e.g. fatigue, speed, time headway, distraction, harsh acceleration)
- Preliminary results indicated a strong relationship between STZ and the independents variables of headway, distance.travelled and TTC
- When more data are available, the most crucial risk indicators of task demand and coping capacity will be extracted

Further Research Directions

- **Expansion of the Safety Tolerance Zone** to other modes and users (Powered Two Wheelers, Cyclists, Pedestrians)

- **Real-time investigation** of the significant risk factors (e.g. weather, distraction and impairment)

- Modification of Safety Tolerance Zone to ensure **safer automated vehicles**

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