

**VERIFICATION
VALIDATION
METHODS**

Mid-Term Presentation 15 / 16 March 2022

Using Ontologies for the Formalization, Recognition, and Analysis of Criticality

Lukas Westhofen, German Aerospace Center (DLR)

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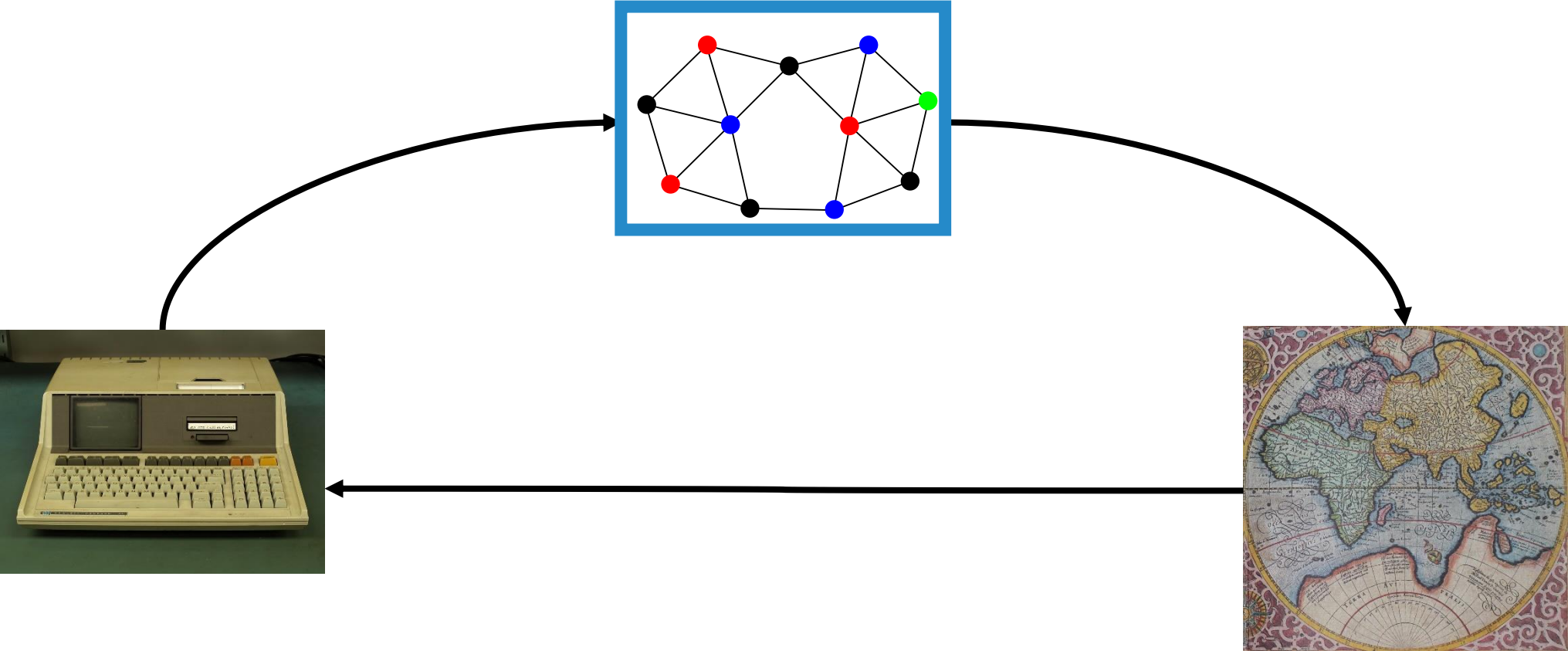


on the basis of a decision
by the German Bundestag

The Complex and Open Context

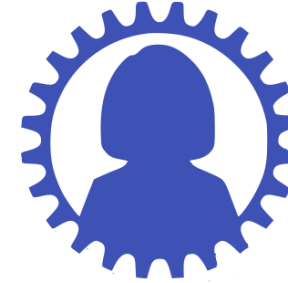


Ontologies to Formalize Conceptualizations





Designer: ‚My ODD shall not contain fog‘



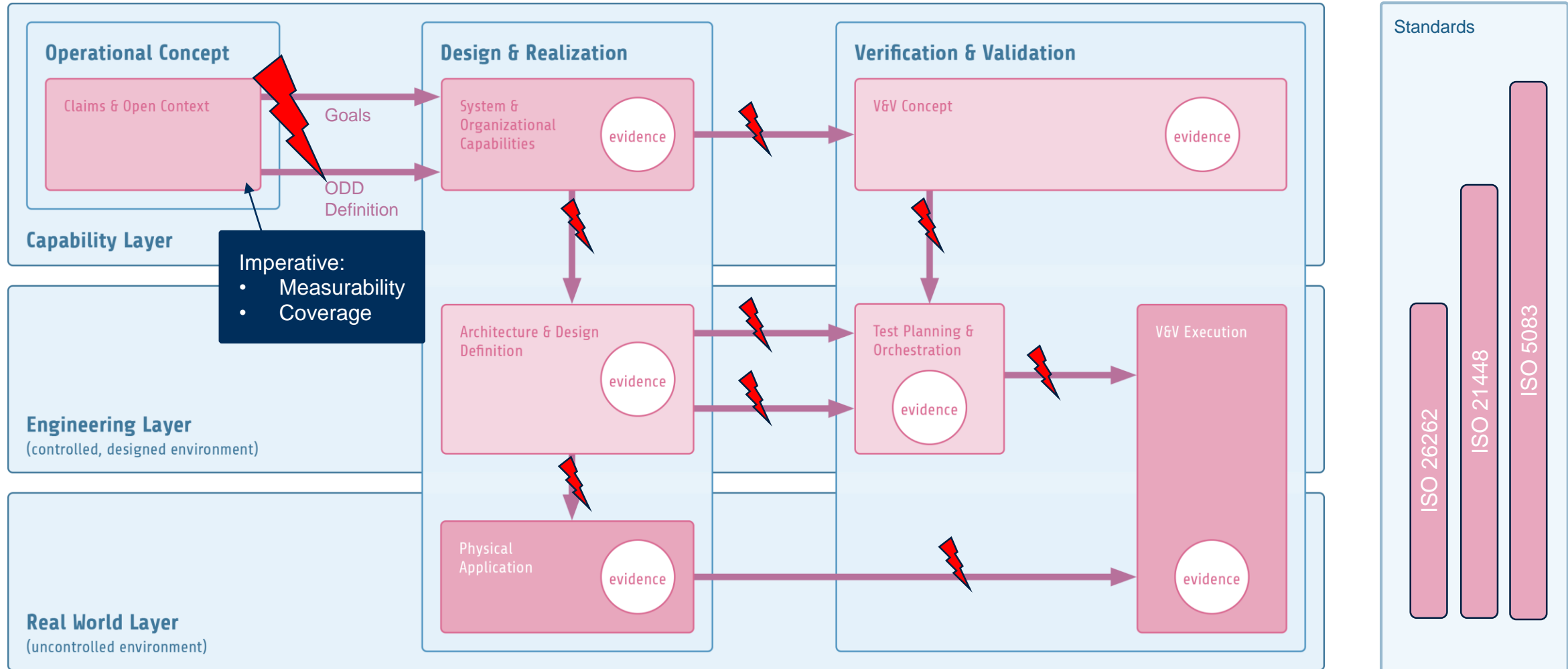
Developer: ‚Ensure that system detects ODD boundary fog‘



Issues:

- What is fog? Does spray classify as fog?
- What is the difference to mist? Same, just another symbol?
- Where does fog end and rain start?
- How do we agree on a suitable definition? How do we organize knowledge?
- ...

Ontologies within a Safety Case



Criticality Phenomena as an Ontological Basis

Fog, Occluded Bicyclist, Heavy Rain, Low Coefficient of Friction, Glare, Highly Reflective Material, Intersection, ...
M...holes,
E...al traffic Signs, Storm,
C...structions Site, Icy Road, Wild Animal
C...y, ...

Catalog of ~300 CPs already identified

Formalization

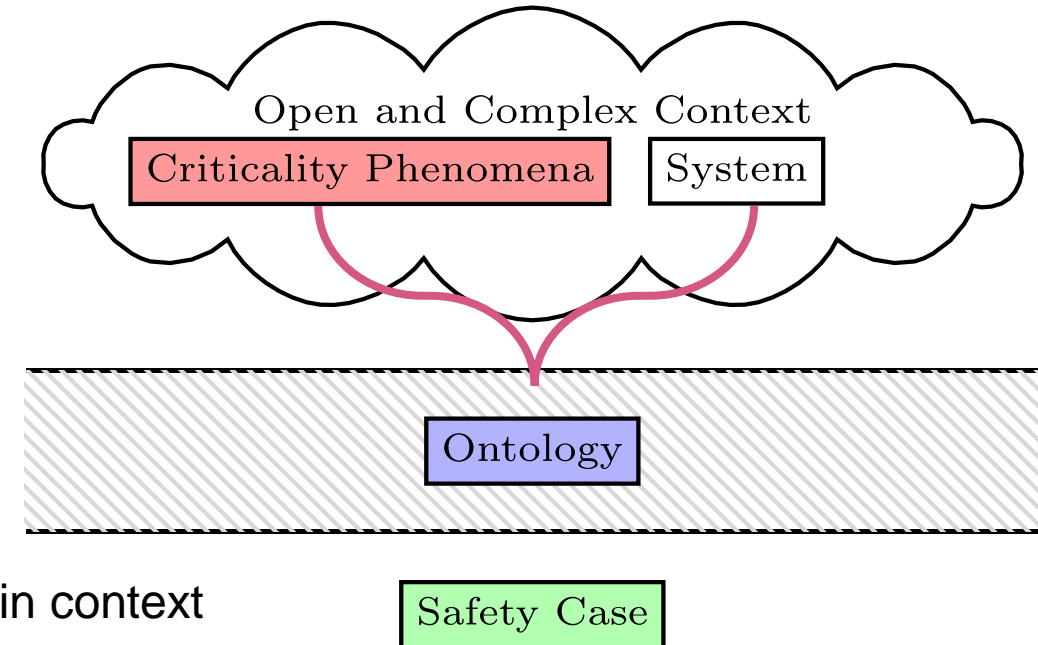
1. Construct ontology from criticality phenomena (CPs)

Recognition

2. Ontology-based recognition of criticality phenomena in context

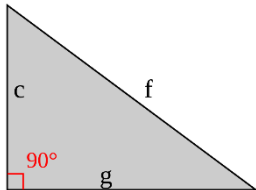
Analysis

3. Usage of criticality phenomena inference in safety case

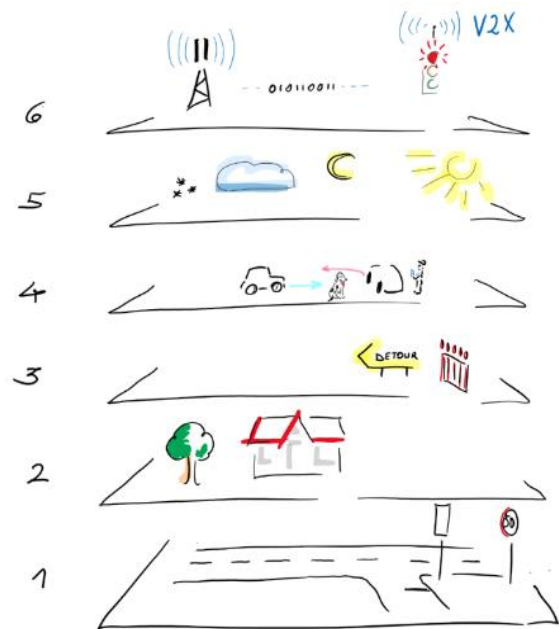


Creating an Ontology from Criticality Phenomena

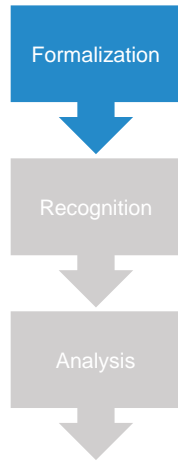
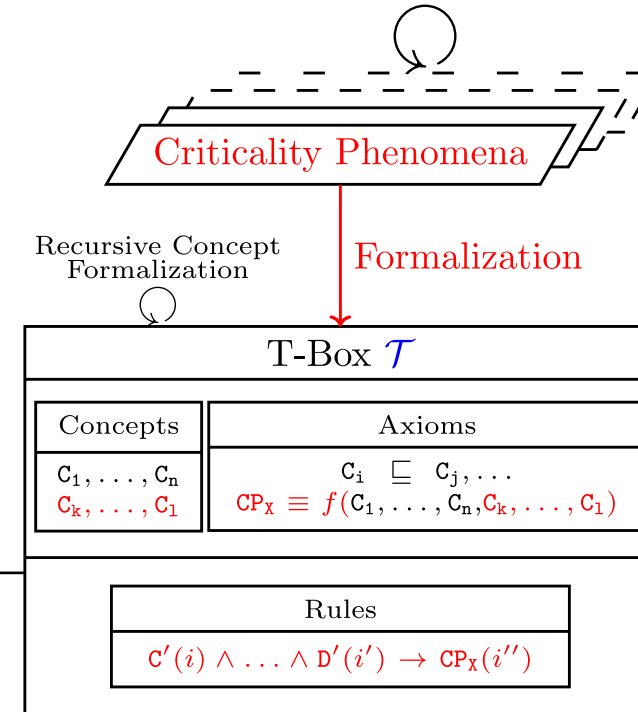
Related Ontologies



6-Layer Model



Standards, Regulations, Domain Experts, ...
Criticality Analysis

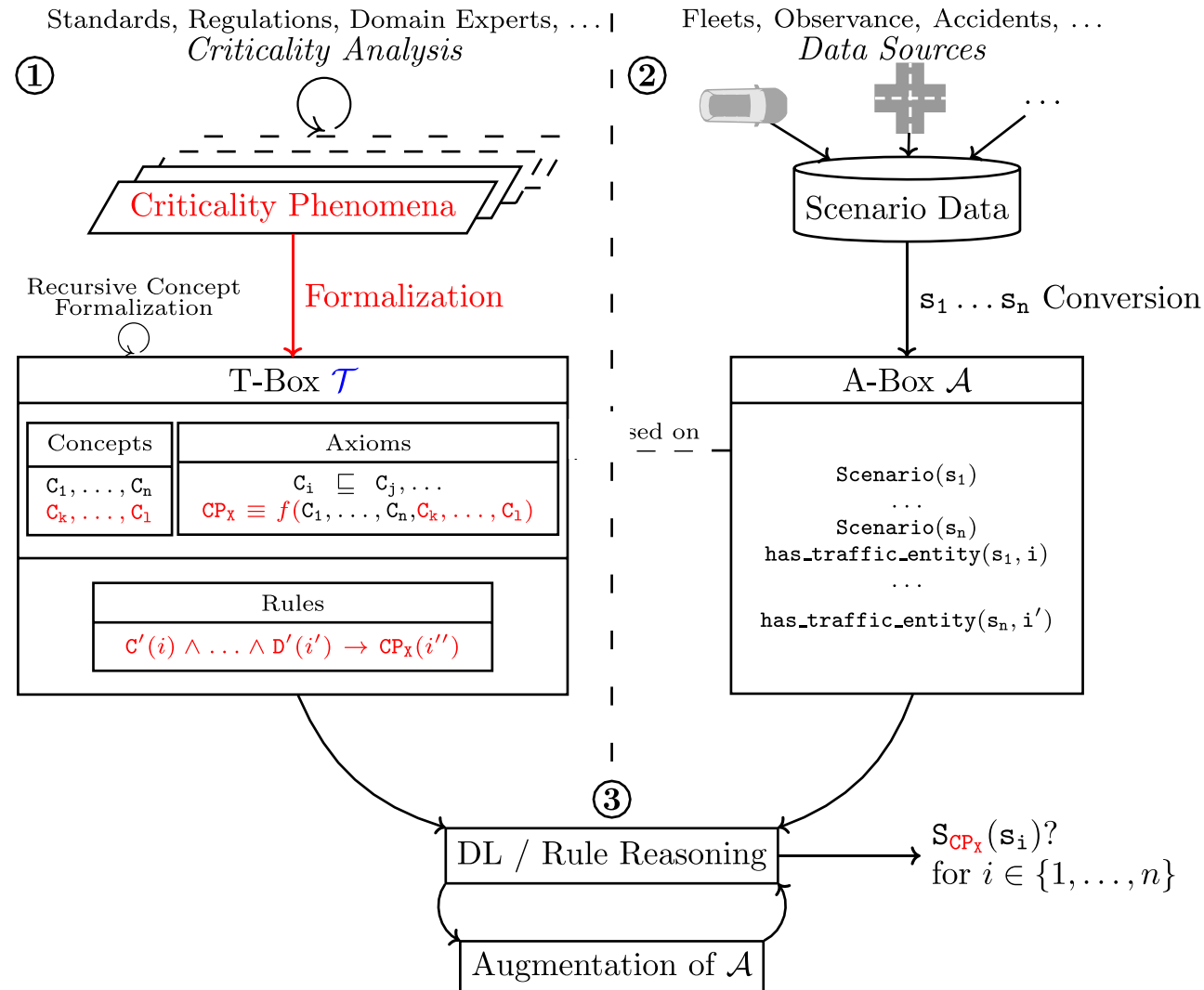
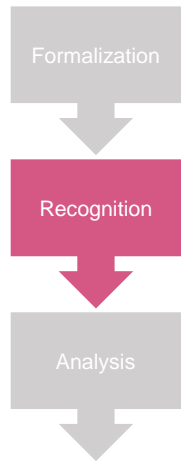


<https://ieeexplore.ieee.org/document/9400833>

Automotive Urban Traffic Ontology (A.U.T.O.)

Find our ontology @GitHub: <https://github.com/lu-w/auto>

Ontology-based Recognition of Criticality Phenomena



Tool Demo



Pellet DL
Reasoner



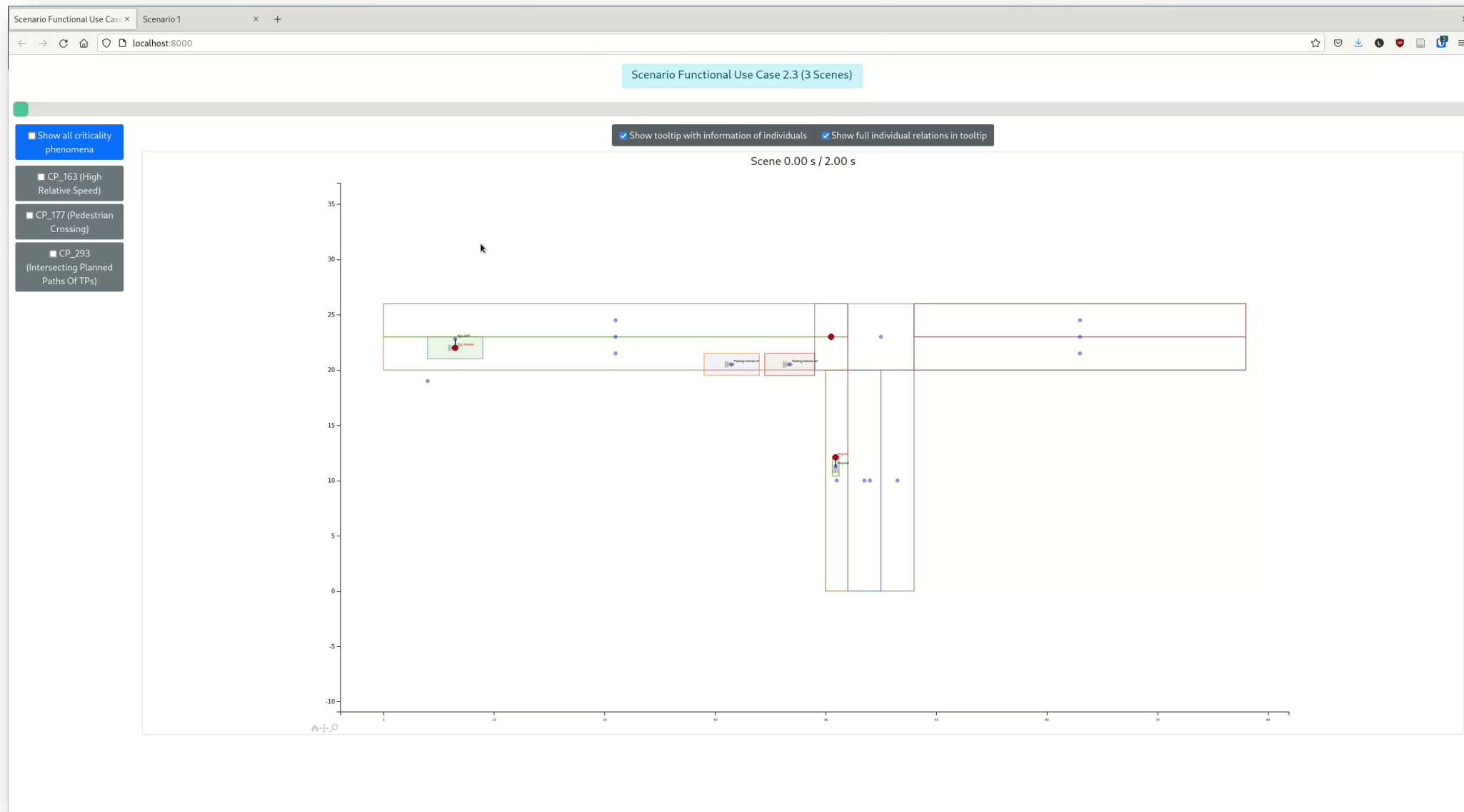
Owready: Ontology-oriented programming in Python with automatic classification and high level constructs for biomedical ontologies

Jean-Baptiste Lamy^{a,*}

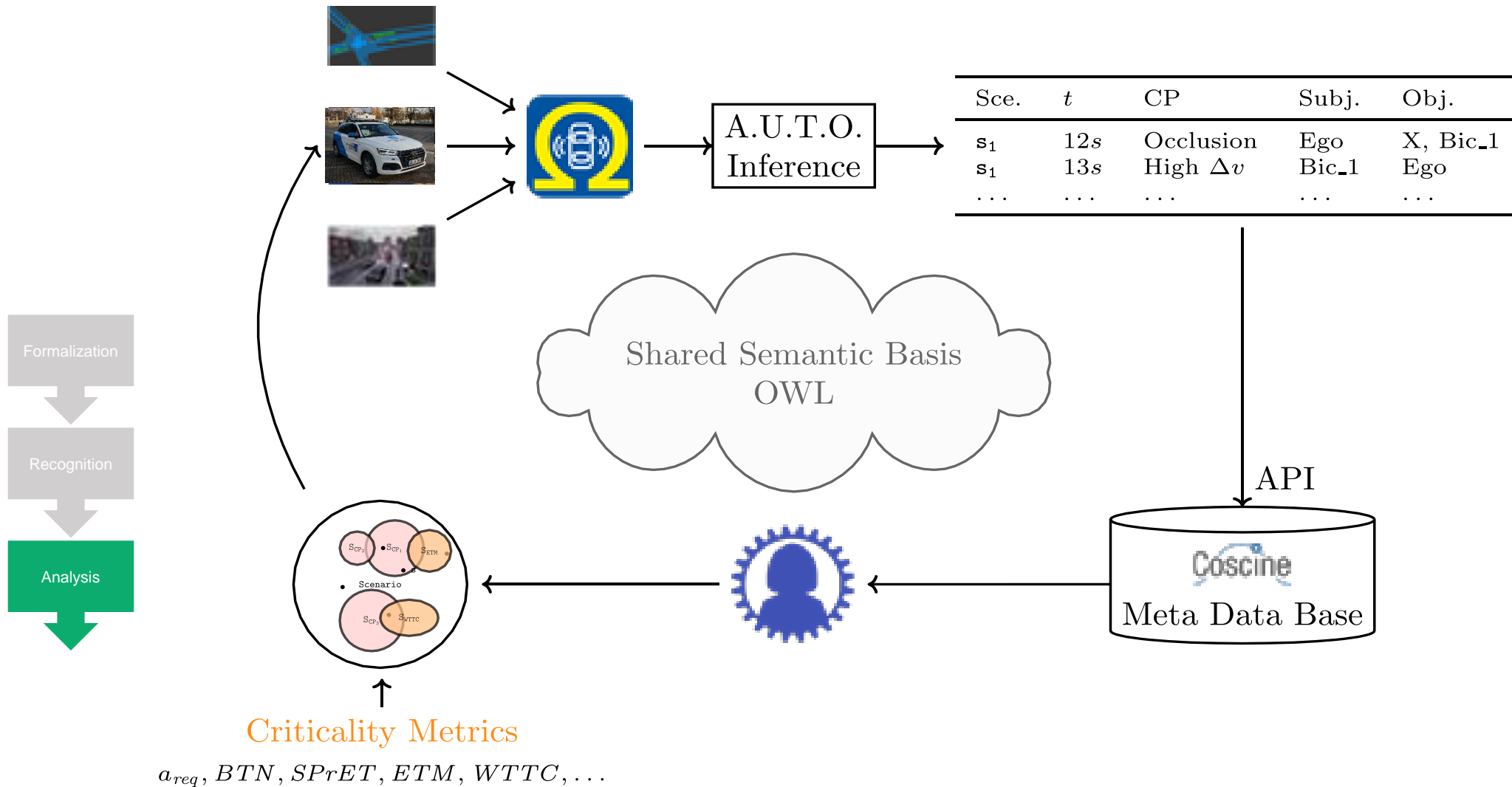
^aLIMICS, Université Paris 13, Sorbonne Paris Cité, 93017 Bobigny, France, INSERM UMRS 1142, UPMC Université Paris 6, Sorbonne Universités, Paris, France

Find our ontology-based tooling @GitHub: <https://github.com/lu-w/criticality-recognition>

Tool Demonstration

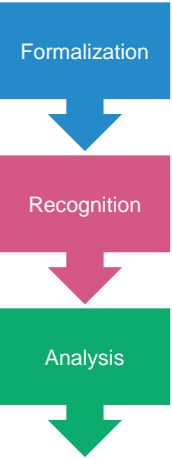


Wrap-Up: Usage of Results in a Safety Case



Interested? Publication Submission Upcoming!

Using Ontologies for the Formalization and Recognition of Criticality for Automated Driving



Using Ontologies for the Formalization and Recognition of Criticality for Automated Driving
Lukas Westhofen, Christian Neuroth, Martin Bunt, Malte Schöles, and Michael Schulze

Abstract—Knowledge representation and reasoning has a long history of examining how knowledge can be formalized, interpreted, and eventually analyzed by machines. In the area of automated vehicles, recent advances suggest the ability to formalize and leverage relevant knowledge as a key enabler in handling the inherently open context of the traffic world. This paper demonstrates a methodology to be a powerful tool for modeling and formalization of and to reasoning about factors associated with criticality in the environment of automated vehicles. For this, we leverage the well-known *4+1* model to create a formal representation of the environmental context. Within this representation, an ontology models domain knowledge as logical entities, enabling distinctions on the presence of critical factors within traffic scenes and scenarios. For covering automated analysis, a joint description logic and rule reasoner is used in combination with an apt rule predicate augmentation. The challenge of the modular approach presents a publicly available implementation, and enables the method by means of a large-scale domain data set of urban traffic scenarios.

Index Terms—Intelligent Vehicles, Ontologies, Vehicle Safety

1. INTRODUCTION

Pursuing the feat of automated driving – i.e. taking human operation out of the control loop – is no contemporary phenomenon. Pushed by pioneers like Ernst Dickmanns as early as the 1980s, it peaked in prestigious research projects such as PROMETHEUS [1] despite focused industry efforts and investor claims, the dream of full driving automation on urban roads has not been realized ever since.

As recognizable by the development of systems of SAE Level 3 [2] – e.g. a traffic jam assist – only to highly restricted operational design domains (ODDs), a key barrier lies within both the complexity and openness of less restricted driving contexts as well as its truly semantic understanding based on a robust perception thereof. Consequently, the development of a system of systems mature enough to overcome the challenges of involved urban scenarios can only be mastered by including stakeholders of a diverse set of disciplines.

It is hence imperative to identify a common conceptualization of the ODD along all parties involved in the system's development.

The research leading to these results is funded by the German Federal Ministry for Economic Affairs and Energy within the project 'V2X – Verification & Validation Methods for Automated Vehicle Level 4 and 5 – Lukas Westhofen and Christian Neuroth' as well as the German Aerospace Establishment (DLR) A.V. Institute of System Engineering for Future Mobility, DLR/DFG Grant 01/2019-1 (Automated Urban Vehicles), German research grants 01/2019-1 (Automated Urban Vehicles), German research grants 01/2019-1 (Automated Urban Vehicles).

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development and operation. Furthermore, this conceptualization must also be comprehensible for machines, as it forms the basis of the interaction of all subsystems of the automated driving system (ADS) with the real world. While for restricted and highly regulated domains such as highways, a model may be feasibly constructed by one expert in a comparatively short time, an urban context has two properties impeding this approach: firstly, it is highly complex, meaning that individuals in such scenarios can be of a vast amount of possible types, each of them possessing a multitude of relevant properties with possibly successively large ranges. Secondly, it is open, meaning that new classes, properties, and behaviors of individuals can emerge readily within the context without prior notice or time to respond. Therefore, a central question arises: how to construct a machine-comprehensible model of open and complex driving contexts?

Earlier work suggests that such operational domain (OD) can be structured through the identification and subsequent explanation of safety-relevant factors, called criticality phenomena [3]. This knowledge can then be contained in a context model, in turn enabling semantic reasoning about these well-understood factors.

For example, such reasoning enables an automated assessment of the situational risk. Often, risk evaluations are performed using so-called criticality metrics [4], for example to guide decisions of the driving automation towards risk-minimal states or to derive relevant test cases within a safety case. Essentially, such metrics are measuring 'late' factors present in traffic conflicts, e.g. (prolonged or observed) small distances and high decelerations. Naturally, the question arises whether the previously derived criticality phenomena can be simultaneously used to approximate the actual risk more precisely.

[5] [6] [7] [8] [9] [10] [11] [12] [13] [14] [15] [16] [17] [18] [19] [20] [21] [22] [23] [24] [25] [26] [27] [28] [29] [30] [31] [32] [33] [34] [35] [36] [37] [38] [39] [40] [41] [42] [43] [44] [45] [46] [47] [48] [49] [50] [51] [52] [53] [54] [55] [56] [57] [58] [59] [60] [61] [62] [63] [64] [65] [66] [67] [68] [69] [70] [71] [72] [73] [74] [75] [76] [77] [78] [79] [80] [81] [82] [83] [84] [85] [86] [87] [88] [89] [90] [91] [92] [93] [94] [95] [96] [97] [98] [99] [100]

ID	Label
A1	label paper
A2	label paper
A3	open vehicle
A4	with attack
T1	highly
T2	criticality phe-
T3	phenomena

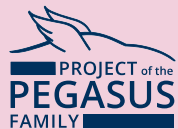
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Find our 6-Layer Model publication @IEEE: <https://ieeexplore.ieee.org/document/9400833>

Thank you!

Lukas Westhofen, DLR



**A project developed by the
VDA Leitinitiative
autonomous and connected driving**

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