

# DIN SPEC 92005:2024-03 (E)

## Artificial Intelligence - Uncertainty quantification in machine learning; Text in English

Inhalt	Seite
Foreword .....	4
Introduction.....	6
1 Scope.....	7
2 Normative references .....	7
3 Terms and definitions.....	7
4 Uncertainties in machine learning .....	13
4.1 The use of “uncertainty” in existing AI standardization.....	13
4.2 Elements of an ML system.....	14
4.3 Uncertainty in machine learning ontology.....	15
4.4 Sources of uncertainty in ML models.....	17
4.5 Uncertainty calibration .....	18
5 Applications of uncertainty quantification in ML .....	19
5.1 Motivation.....	19
5.2 Runtime monitoring.....	20
5.3 Transfer learning .....	20
5.4 Out-of-distribution detection .....	20
5.5 Active learning .....	21
5.6 Reinforcement learning .....	21
5.7 Fusion.....	21
6 Uncertainty quantification approaches and properties .....	22
6.1 Introduction and motivation .....	22
6.2 Probabilistic models.....	22
6.3 Uncertainty quantification methods .....	22
6.3.1 Introduction .....	22
6.3.2 Model-agnostic methods.....	23
6.3.3 Model-specific methods.....	23
6.4 Properties of uncertainty quantification approaches .....	23
7 Requirements and recommendations .....	24
7.1 System dependencies.....	24
7.2 Situation awareness .....	25
7.3 Sources.....	25
7.4 Factors .....	25
7.5 Separation of concerns .....	25
7.6 Agnosticism .....	25
7.7 Statistical confidence .....	25
7.8 Calibration .....	26
7.9 Overconfidence .....	26
7.10 Interpretability, transparency and human-understandability of the uncertainty quantification results.....	26
7.11 Explainability, transparency and human-understandability of the uncertainty quantification approach.....	26
7.12 System integration .....	26
Annex A (informative) Types of uncertainty: aleatoric and epistemic.....	28
Annex B (informative) Exemplary uncertainty calibration metrics and methods .....	29

<b>Annex C (informative) Use cases.....</b>	<b>35</b>
<b>C.1 Uncertainty quantification for sensor fusion during landing of an aerial vehicle.....</b>	<b>35</b>
<b>C.1.1 Use case definition.....</b>	<b>35</b>
<b>C.1.2 Solution via uncertainty quantification.....</b>	<b>35</b>
<b>C.1.3 Examples of relevant requirements and recommendations.....</b>	<b>38</b>
<b>C.2 Uncertainty quantification for traffic sign recognition.....</b>	<b>39</b>
<b>C.2.1 Use case definition.....</b>	<b>39</b>
<b>C.2.2 Solution via uncertainty quantification.....</b>	<b>39</b>
<b>Bibliography.....</b>	<b>42</b>

## Figures

<b>Figure 1 — Overview of uncertainty quantification ontology.....</b>	<b>15</b>
<b>Figure 2 — Overview of sources and layers of uncertainty.....</b>	<b>18</b>
<b>Figure B.1 — Reliability diagram for examining uncertainty calibration for categorical variables ...</b>	<b>33</b>
<b>Figure B.2 — Reliability diagrams for examining uncertainty calibration for continuous random variables [70].....</b>	<b>34</b>
<b>Figure C.1 — Drone landing use case.....</b>	<b>35</b>
<b>Figure C.2 — Drone landing system architecture.....</b>	<b>37</b>
<b>Figure C.3 — Exemplary drone camera image with probabilistic landing pad detection [74].....</b>	<b>37</b>
<b>Figure C.4 — Exemplary drone state and uncertainty evolution without and with POD fusion over time.....</b>	<b>38</b>
<b>Figure C.5 — Schematic uncertainty wrapper — Additional external information sources for the uncertainty wrapper and its outcomes.....</b>	<b>40</b>
<b>Figure C.6 — Decision tree example considering semantic factors [43].....</b>	<b>41</b>

## Tables

<b>Table A.1 — Overview of aleatoric and epistemic uncertainty.....</b>	<b>28</b>
<b>Table B.1 — Common metrics for measuring uncertainty calibration of an ML model for categorical and continuous random variables.....</b>	<b>29</b>
<b>Table B.2 — Common (post-hoc) uncertainty calibration methods for the correction of possibly uncalibrated uncertainty estimates of an ML model for categorical and continuous random variables.....</b>	<b>31</b>