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Baseline Review of Formal Methods and Foundations of Artificial Intelligence

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Abstract

Artificial Intelligence (AI) is advancing rapidly, yet many successful models remain opaque and provide limited assurance about reliability, safety, and failure modes. This motivates renewed interest in formal methods and foundational perspectives that can support trustworthy AI beyond empirical testing.

This extended abstract outlines a planned concept-centric baseline review of the selected papers volume of the inaugural International Conference on Formal Methods and Foundations of Artificial Intelligence (FMF-AI 2025), published as *Annales Mathematicae et Informaticae*, Vol. 61 (2025). The goal is twofold: (i) to map and summarize the first FMF-AI "snapshot" as a starting point for the Hungarian research ecosystem, and (ii) to define a reproducible baseline that can serve as a reference for measuring topical and methodological shifts in subsequent FMF-AI editions. We follow a structured scoping-review mindset: for each paper we extract the addressed problem, the main method family (learning-based, optimization/heuristics, symbolic/formal, or hybrid), the evidence type (empirical evaluation, user study/survey, theoretical analysis, or formal guarantee), and the paper's explicit connection to trustworthy AI (robustness, assurance, verification, or safety-related reasoning). We then cluster the volume into five thematic groups and record their relative prevalence.

Group I (Formal verification for trustworthy AI) contains a single contribution that explicitly couples empirical evaluation with *formal verification* of robustness properties in neural network ensembles, making it the most direct realization of the conference's "formal methods for AI reliability" promise in the selected papers volume [14]. Group II (Robustness, anomaly/fault detection, and dependability in data-driven AI) addresses reliability concerns through empirical

and engineering-oriented approaches, including video anomaly detection, signal interpretation, robustness/noise-sensitivity analyses, and log-based fault diagnosis [2, 4, 11, 13]. Group III (NLP and Hungarian language technology, including AI-generated text analyses) covers Hungarian toxic comment detection, syntactic comparisons of human vs. AI-written scientific text, and the enhancement of a Hungarian conversational model, reflecting both local-language priorities and emerging challenges around generative AI [9, 19, 20]. Group IV (AI in education and human factors) captures the strong educational and societal dimension of FMF-AI 2025, spanning constraint-based fair team formation (using SMT) in STEAM activities, adaptive testing with Item Response Theory, AI-enabled robotics for higher education, the impact of LLM usage on algorithmic thinking, and a survey of Hungarian students' AI attitudes [1, 3, 6, 12, 15]. Group V (Foundations and algorithms: optimization, graphs, and systems/program methods) emphasizes algorithmic and modeling foundations through program refactoring with GNNs, the transition from rule-based to learned behaviors, multi-objective evolutionary scheduling, graph coordination under risk, probabilistic modeling for sports betting strategies, an Industry 4.0 reference architecture model, and community detection via overlapping label propagation [5, 7, 8, 10, 16–18].

A central baseline observation is that, despite the conference title, *explicit* formal verification appears in only one selected paper (Group I), while the majority of contributions approach reliability and correctness indirectly (empirical robustness studies, anomaly/fault detection, or algorithmic modeling). We interpret this underrepresentation not as a lack of relevance, but as an indicator of the intrinsic difficulty and tooling barriers of scaling formal methods to modern AI pipelines. Our review synthesizes cross-cutting themes (robustness vs. guarantees, evaluation practices, artifact transparency, and Hungary-specific language/education perspectives) and proposes simple baseline metrics (papers-per-group counts, prevalence of formal guarantees, evidence-type distribution) that can be recomputed for future FMF-AI volumes to assess progress over time.

Transparency note: The author is a co-author of two papers in the reviewed volume. The review follows a descriptive, taxonomy-driven approach and does not involve ranking, evaluation, or endorsement of individual contributions, therefore, no partiality is present.

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