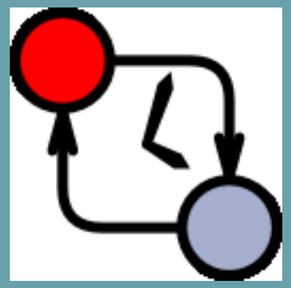


UPPAAL

NARZĘDZIE DO MODELOWANIA I WERYFIKACJI SYSTEMÓW CZASU RZECZYWISTEGO

PRESENTATION BASED ON:

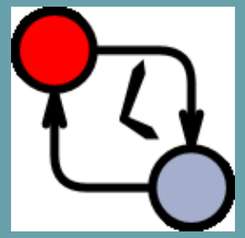
sensors

GROBELNA I, GAJEWSKI K, KARATKEVICH A.
A SYSTEMATIC REVIEW ON THE APPLICATIONS OF UPPAAL SENSORS. 2025; 25(11):3484

Seminarium Katedry Informatyki Stosowanej AGH, 18 czerwca 2025

WPROWADZENIE

Czym jest UPPAAL?



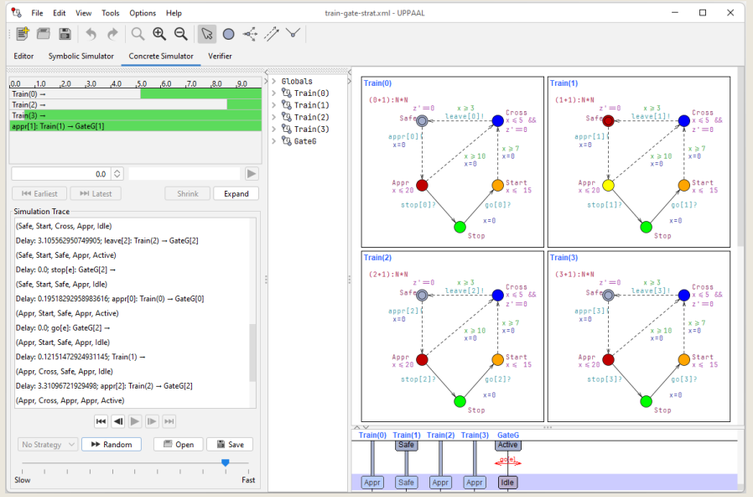
- Zintegrowane środowisko narzędziowe do modelowania, symulacji i weryfikacji systemów czasu rzeczywistego
- Oparte na teorii automatów czasowych
- Stosowane do weryfikacji systemów, które mogą być modelowane jako sieci niedeterministycznych procesów z ograniczoną strukturą kontrolną

UPPSALA UNIVERSITET

AALBORG UNIVERSITY

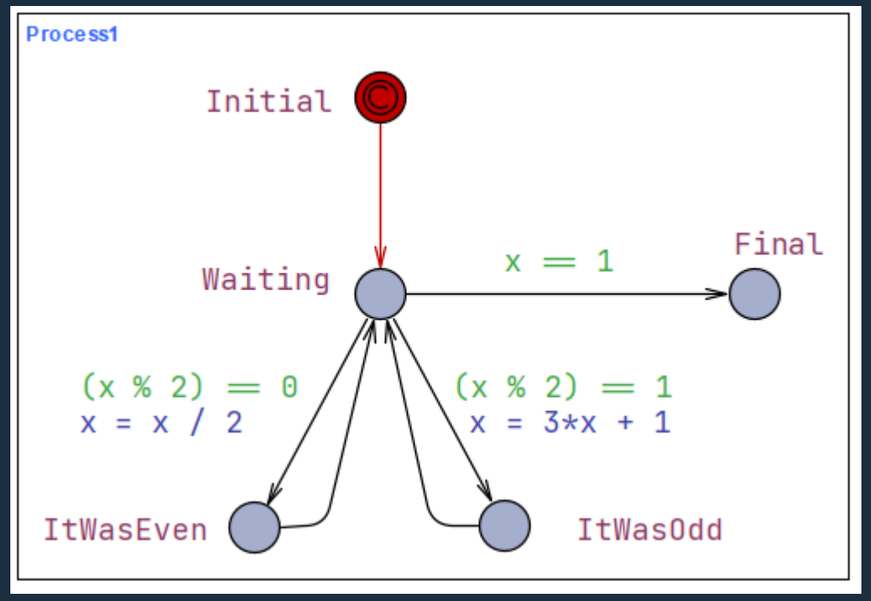
Historia i rozwój UPPAAL

- 1990: Teoria automatów czasowych (Rajeev Alur, David Dill)
- 1995: Pierwsze wydanie UPPAAL 1.99
- 1999: UPPAAL2k – pierwsza „nowoczesna” wersja (3.0 beta) z GUI
- 2012-2019: Seria wersji 4.x z nowymi funkcjonalnościami
- Ciągły rozwój z nowymi rozszerzeniami i ulepszeniami
- Aktualna wersja: 5.0



Zasada działania

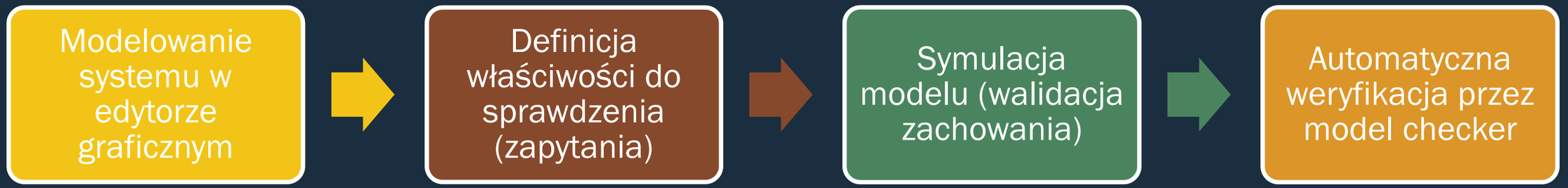
podstawy teoretyczne



- Automaty czasowe (*Timed Automata*):
  - Rozszerzenie automatów skończonych o zmienne czasowe (zegary)
  - Wszystkie zegary postępują synchronicznie

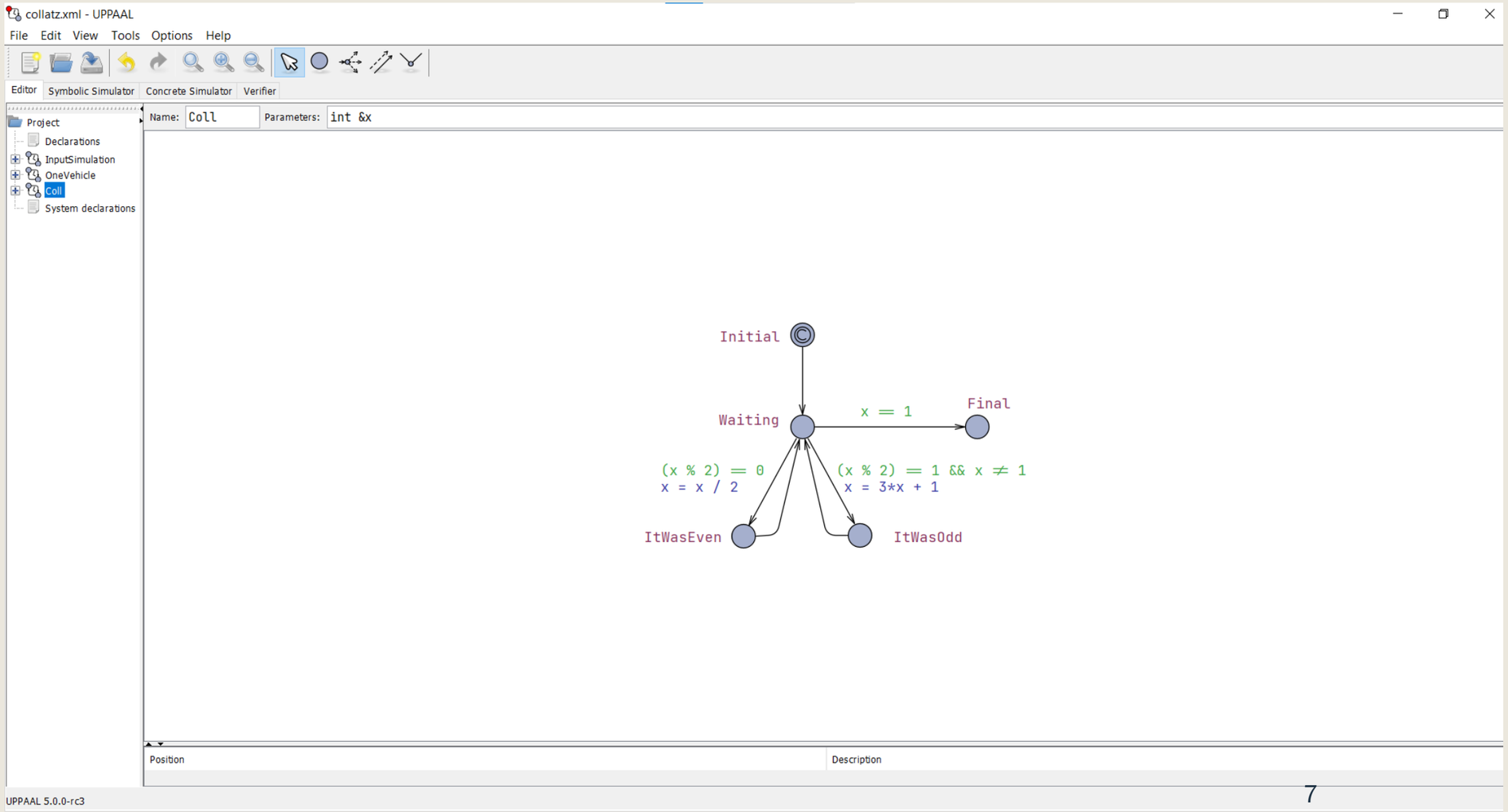
- Sieci automatów czasowych:
  - System modelowany jako sieć równoległych automatów czasowych
  - Komunikacja przez kanały synchronizacji lub zmienne wspólne
  - Rozszerzenie o zmienne dyskretne (całkowite, tablice)

Zasada działania - weryfikacja w praktyce



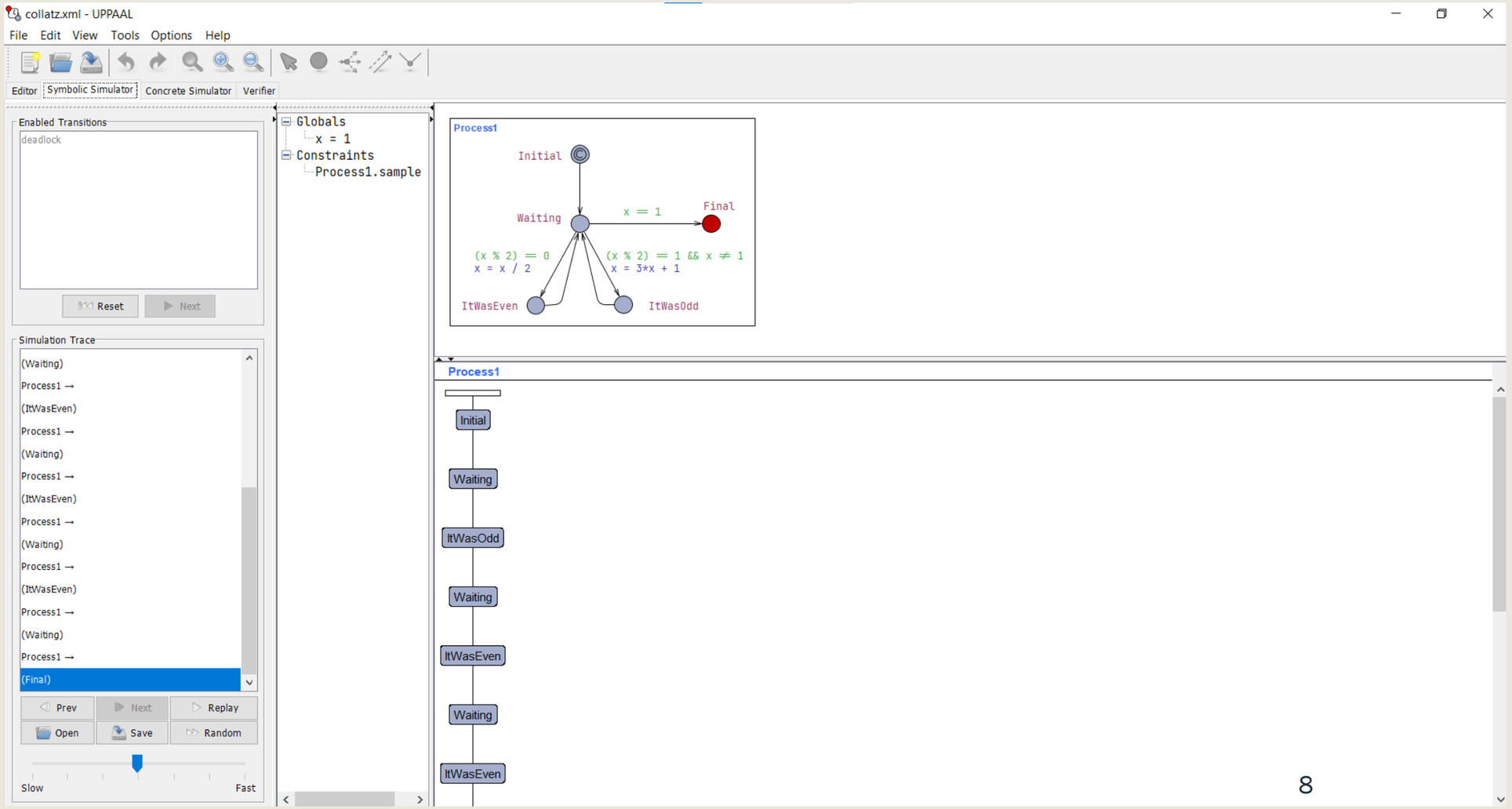
Komponenty UPPAAL

Edytor stanowi graficzny interfejs użytkownika umożliwiający tworzenie modeli systemów w postaci sieci automatów czasowych. Użytkownicy mogą rysować automaty, definiować zmienne, kanały komunikacyjne oraz funkcje systemowe.



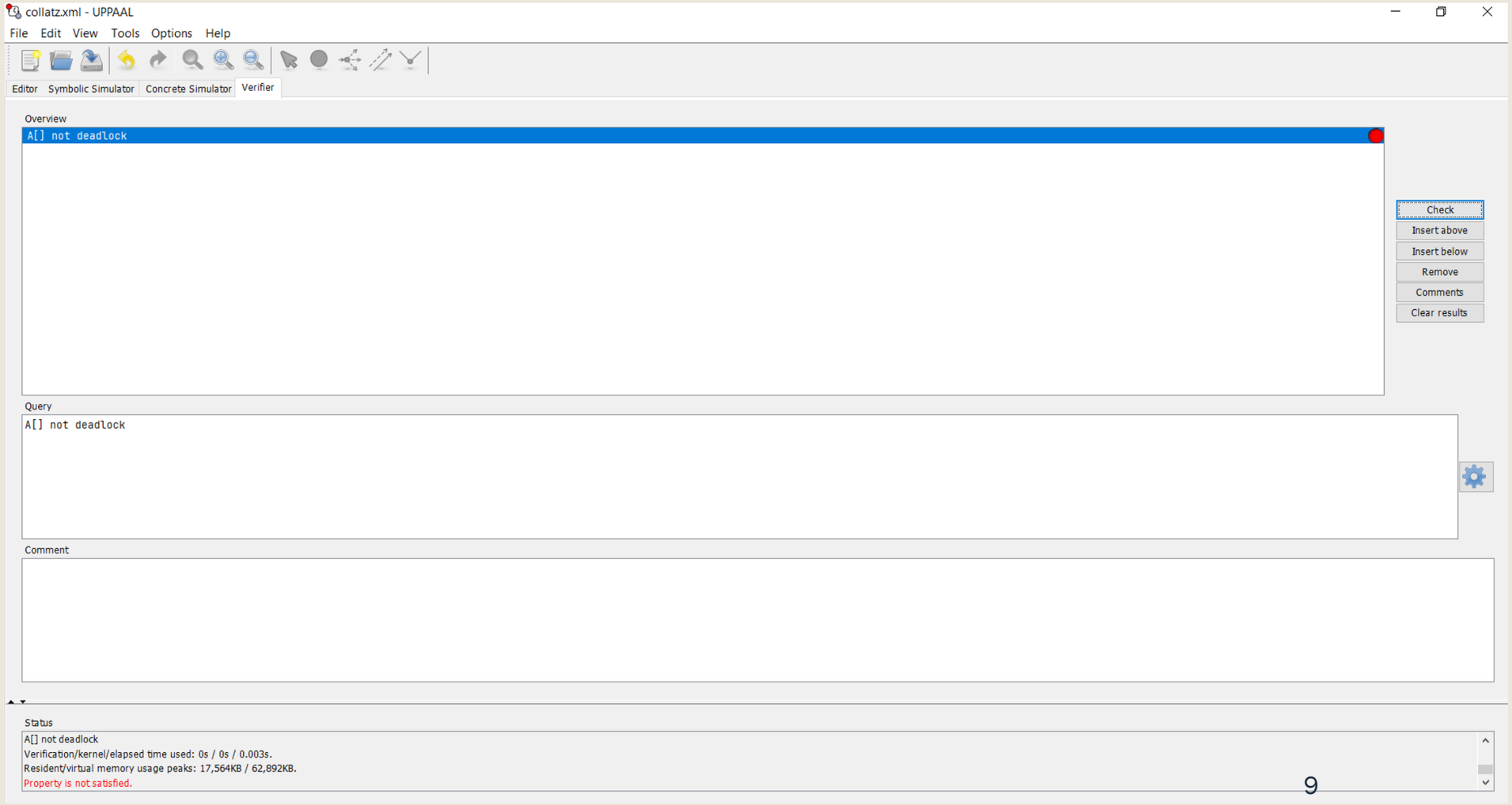
Komponenty UPPAAL

Symulator służy jako narzędzie walidacji, które umożliwia interaktywną eksplorację możliwych zachowań dynamicznych systemu. Pozwala on na badanie wykonania modelu w czasie projektowania. Symulator może również wizualizować ślady diagnostyczne generowane przez weryfikator.



Komponenty UPPAAL

Weryfikator przeprowadza automatyczne sprawdzanie właściwości przez eksplorację przestrzeni stanów systemu.



Wersje i rozszerzenia UPPAAL

UPPAAL Basic

Podstawowe narzędzie do modelowania i weryfikacji

UPPAAL CORA

Analiza osiągalności z optymalizacją kosztów

UPPAAL TIGA

Analiza gier czasowych, synteza kontrolerów

UPPAAL SMC

Statystyczne sprawdzanie modeli

UPPAAL Stratego

Synteza strategii

UPPAAL TRON

Testowanie systemów online

RESEARCH METHODOLOGY

Information sources and search strategy

- We searched for the keyword “uppaal” in the titles or abstracts of papers indexed in the scientific databases IEEE Xplore, Elsevier, Springer, ACM, MDPI, and Google Scholar.
- The search was conducted twice, the first time in September–October 2023 and the second time in January–February 2024.
- The resulting papers were judged on the basis of abstract scanning.
- If this was insufficient, a full scan of the article was performed to check whether they were compatible with the inclusion and exclusion criteria.

Research questions

- **RQ1:** What are the application areas of the UPPAAL tool?
- **RQ2:** Which version of UPPAAL is used the most?
- **RQ3:** Which keywords appear the most often in the obtained papers?
- **RQ4:** What does the distribution of research papers regarding access options, scientific databases, and types of publication look like?
- **RQ5:** What does the distribution of research papers regarding geographical location look like?

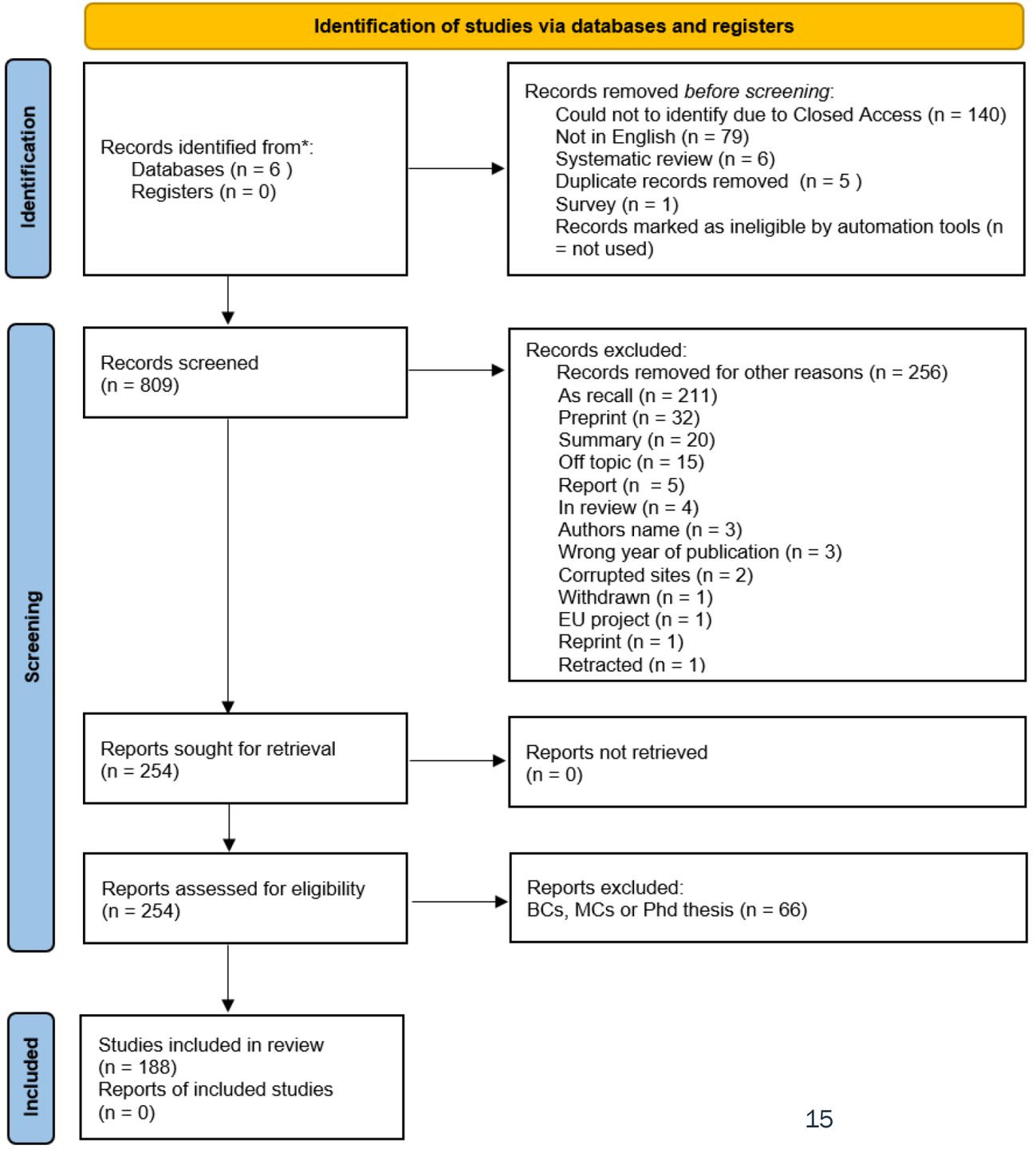
Eligibility criteria

- IC1: Papers published in 2022 and 2023.
- IC2: Research using UPPAAL as the main tool.

- EC1: Papers not written in English.
- EC2: Review articles.
- EC3: Papers whose scope was to compare various tools.
- EC4: Papers that could not be evaluated due to very limited access.

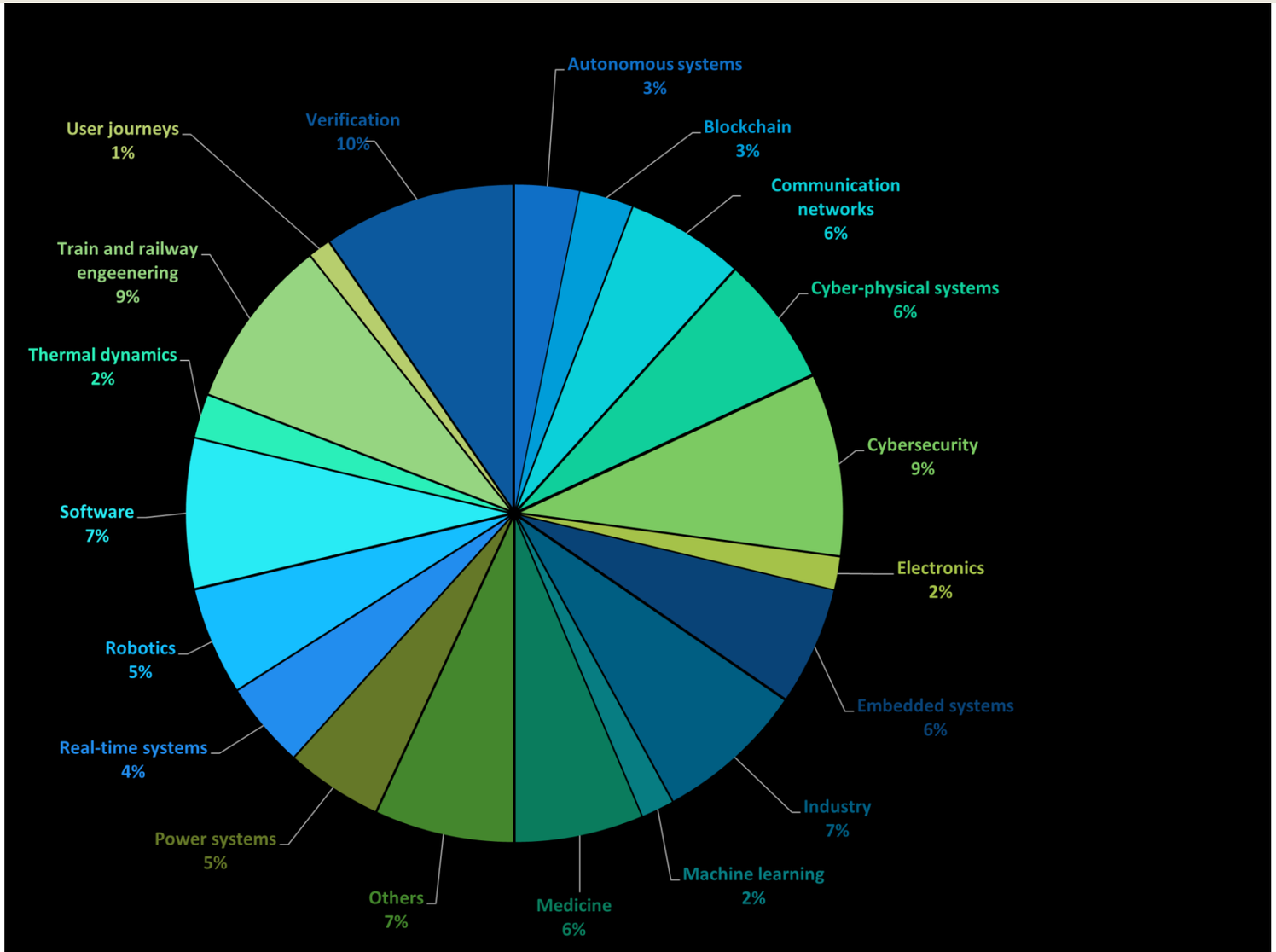
Data extraction, storage and analysis

- The initial search in six databases resulted in **1040** papers.
- **188** papers were chosen for further detailed analysis.

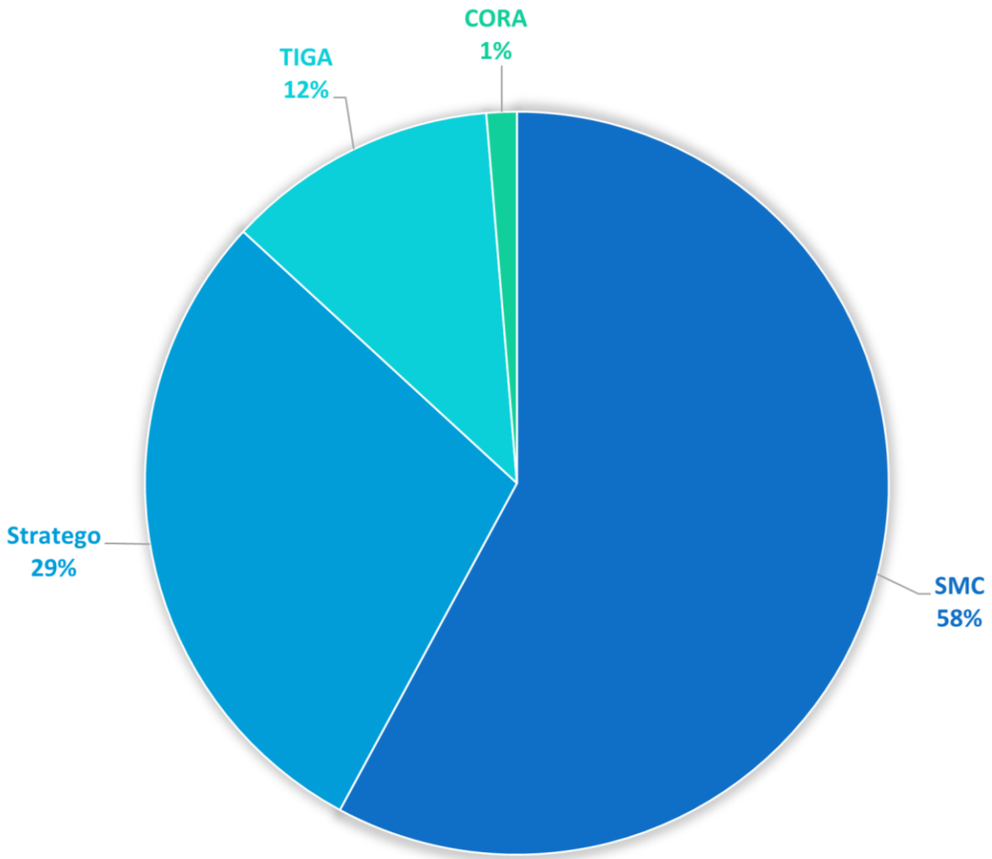


RESULTS

RQ1: What are the application areas of the UPPAAL tool?

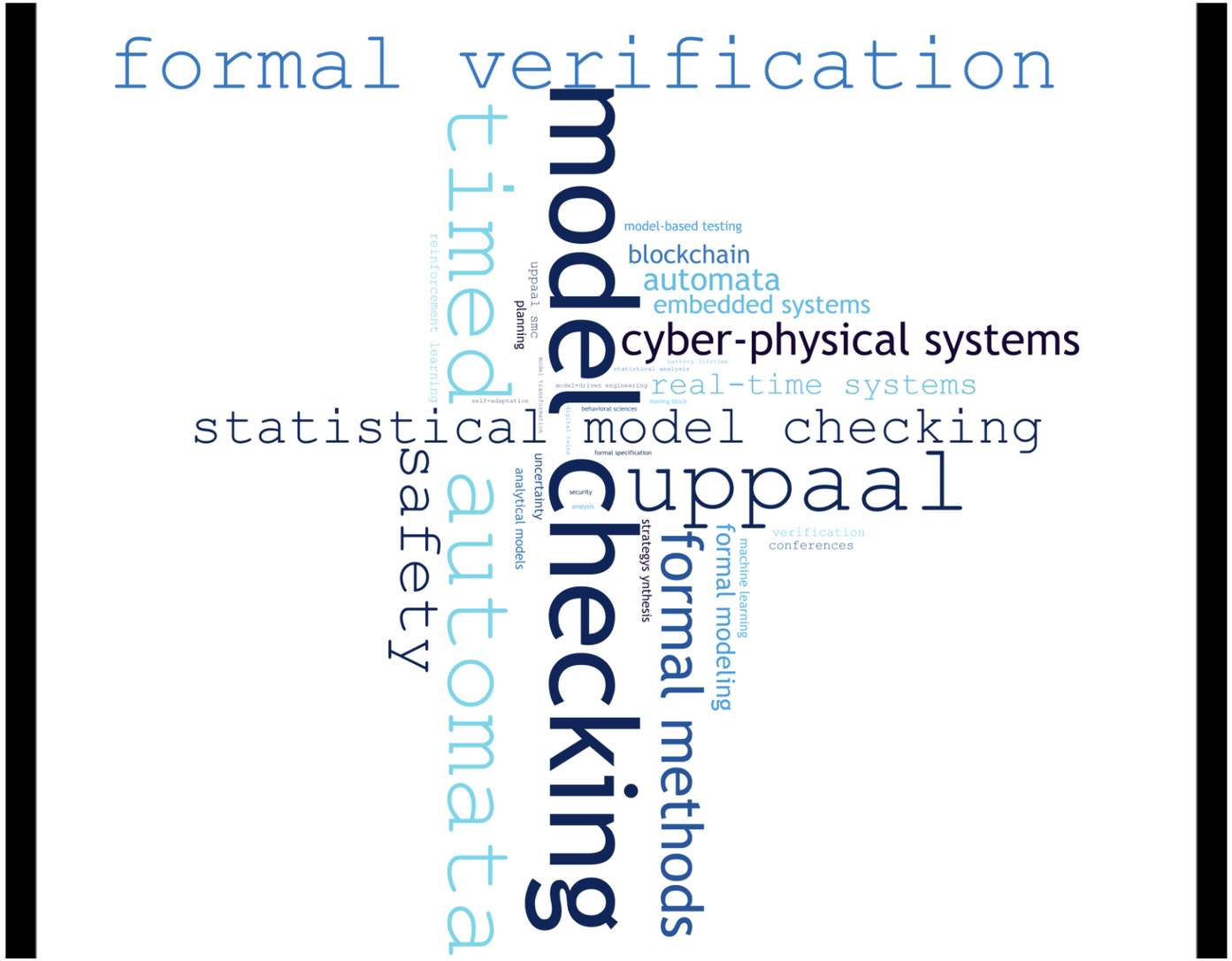


RQ2: Which version of UPPAAL is used the most?



* results based on the analysis of papers that explicitly reported the tool version (n = 76)

RQ3: Which keywords appear the most often in the obtained papers?



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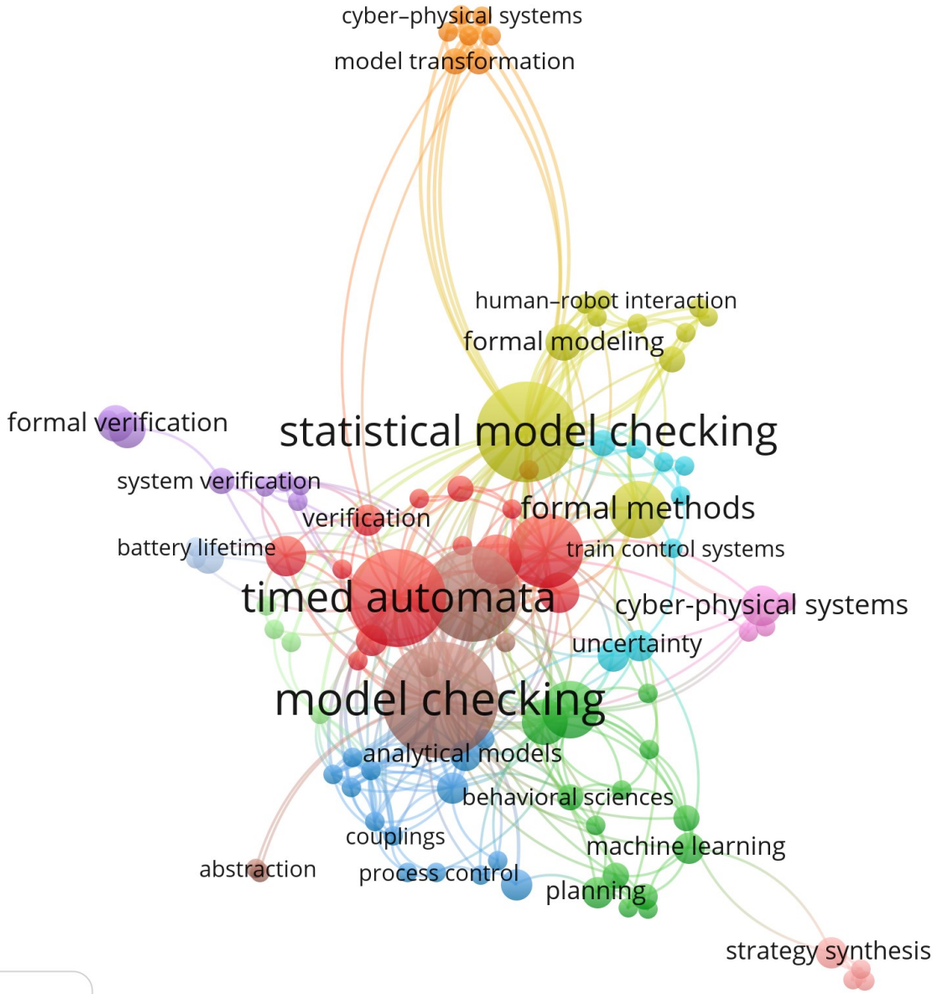

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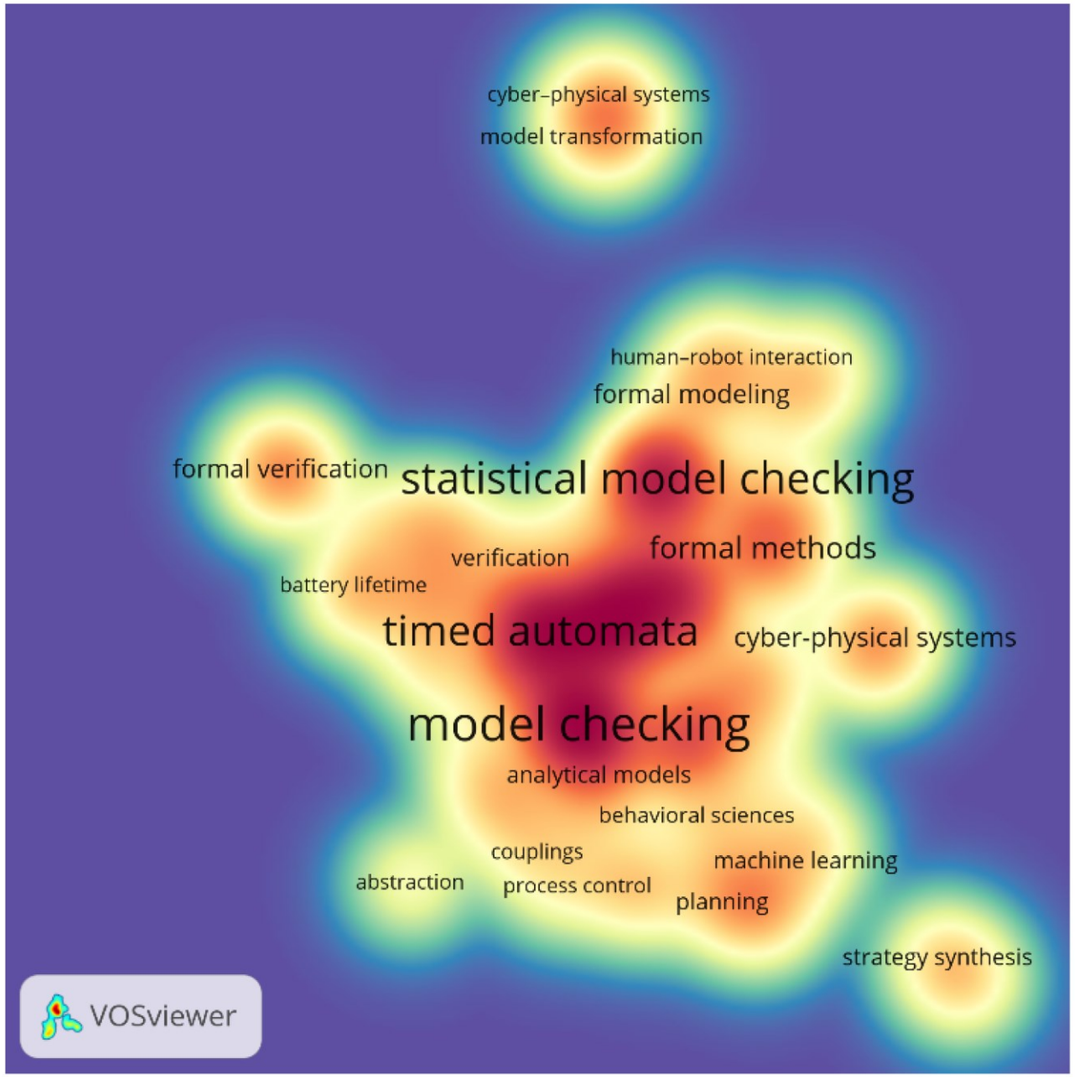
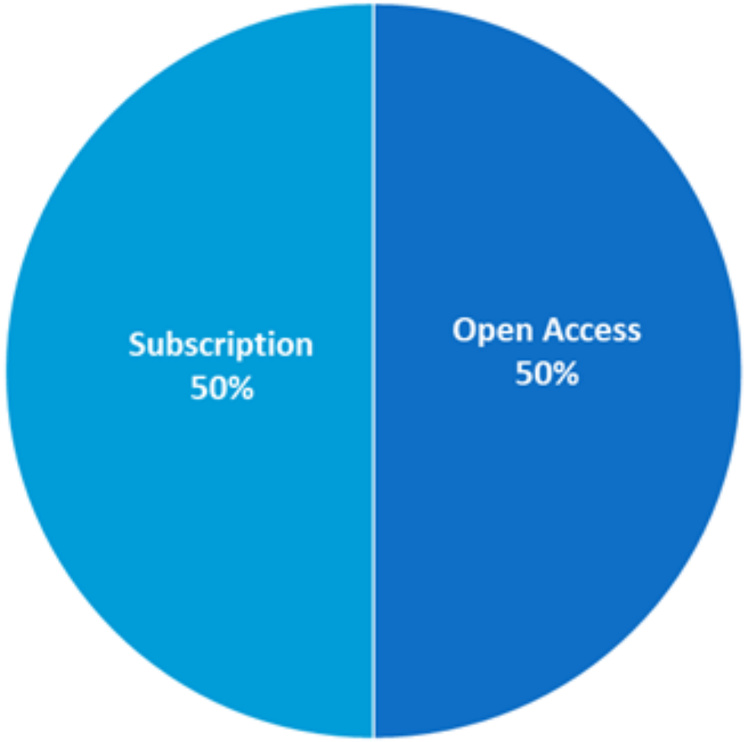
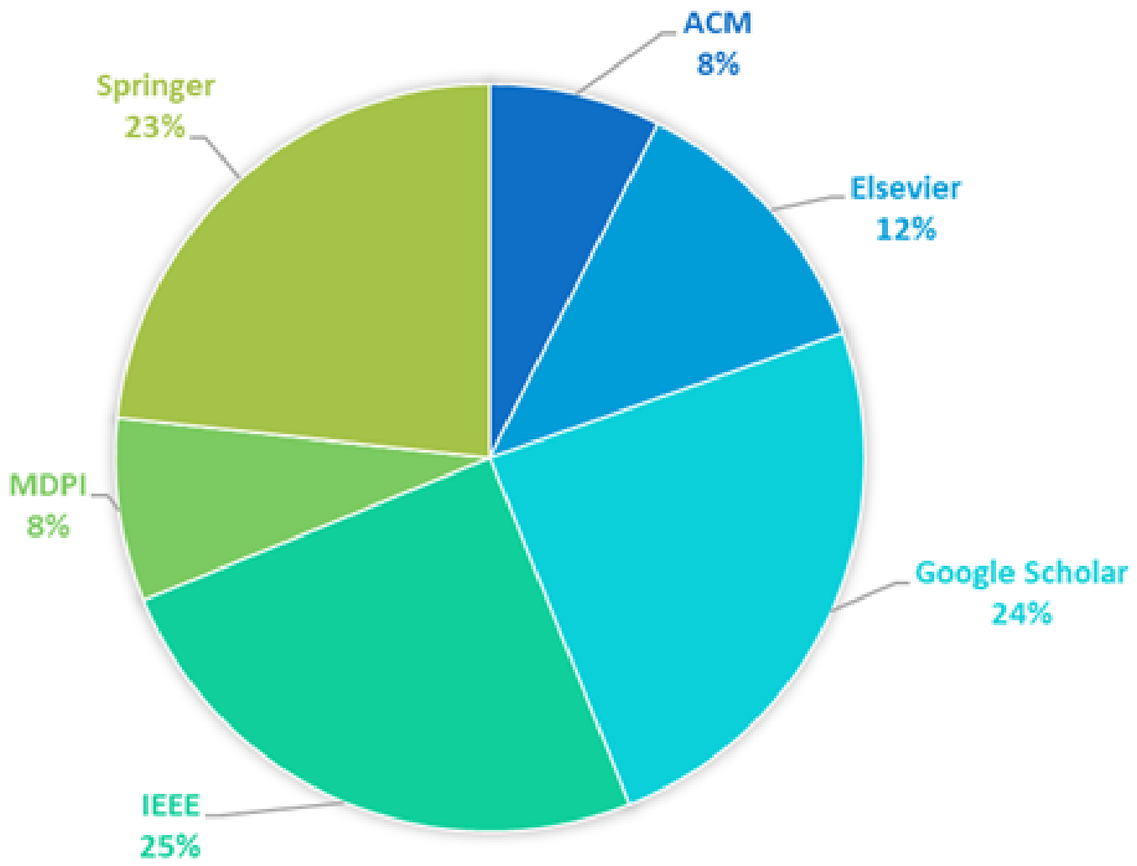


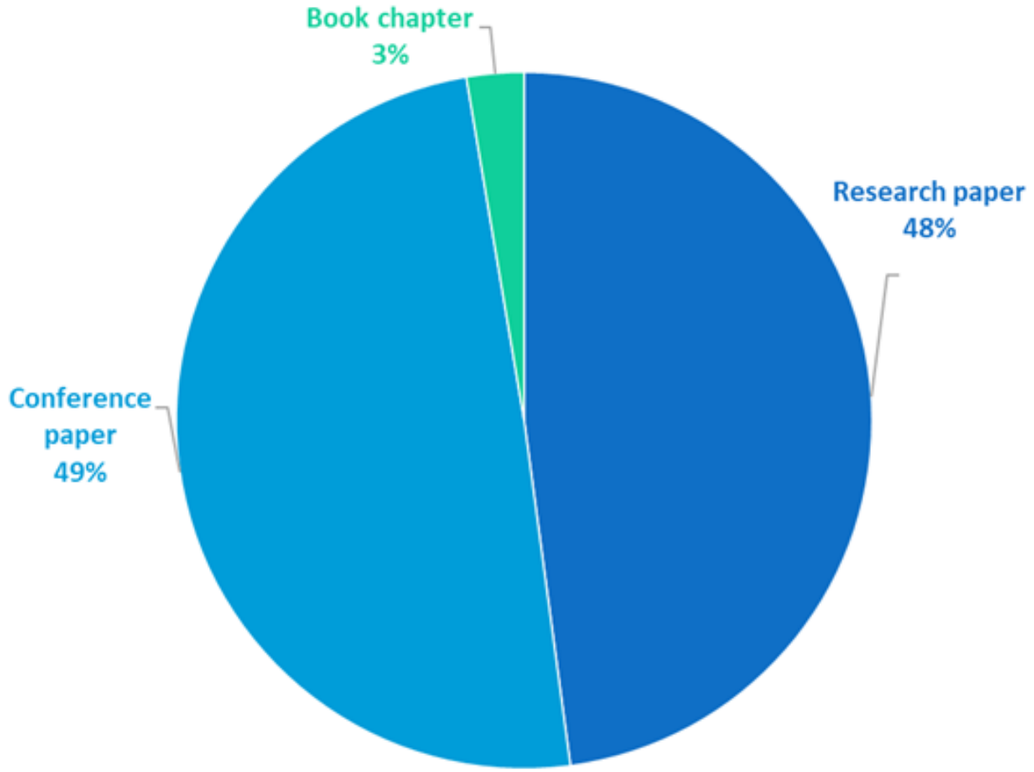
RQ4: What does the distribution of research papers regarding access options look like?



RQ4: What does the distribution of research papers regarding scientific databases look like?

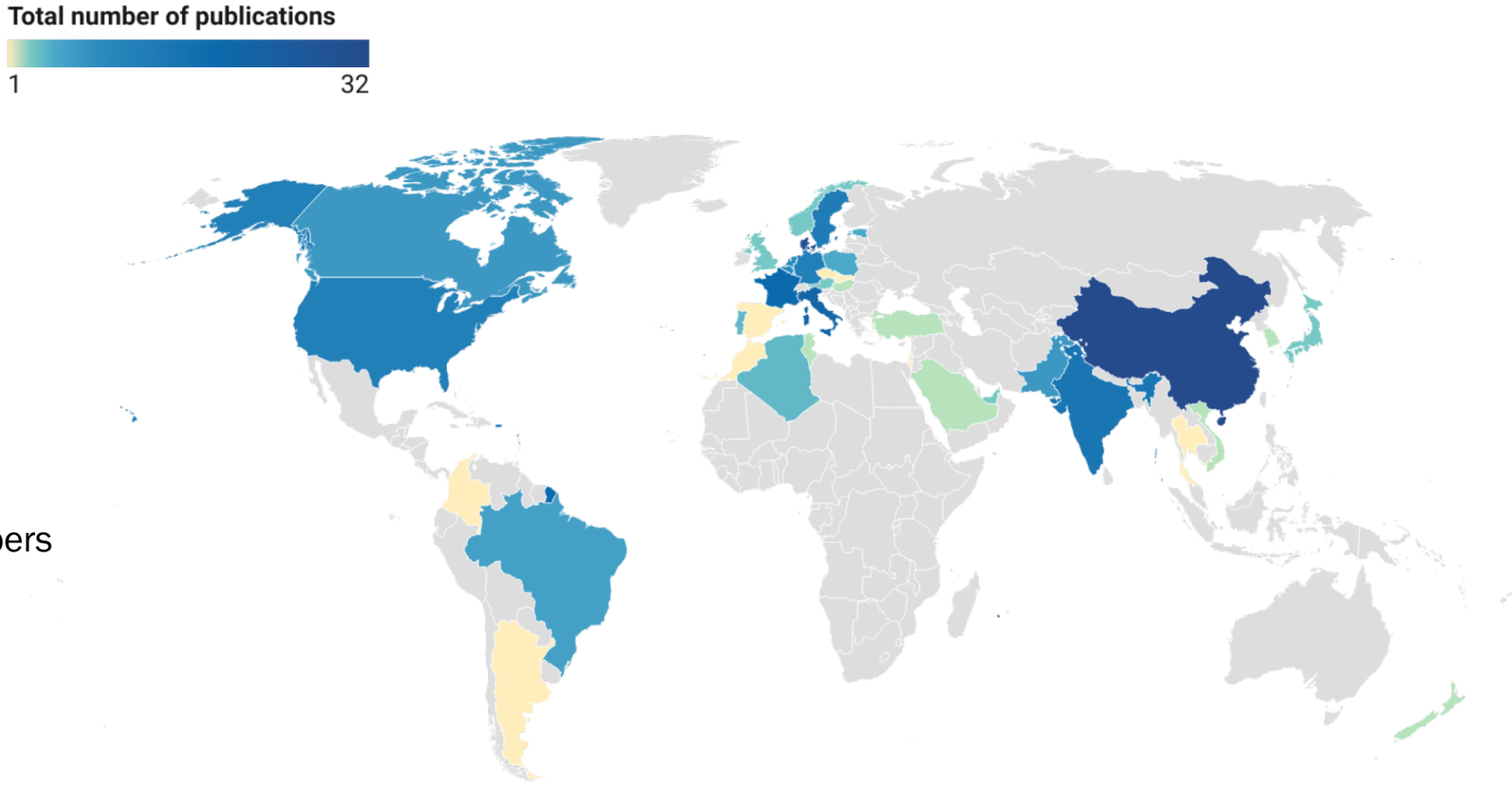


RQ4: What does the distribution of research papers regarding types of publication look like?



RQ5: What does the distribution of research papers regarding geographical location look like?

TOP 10
China: 32 papers
Denmark: 30 papers
Italy: 21 papers
France: 19 papers
India: 15 papers
Sweden: 13 papers
Germany: 12 papers
United States of America: 11 papers
Belgium: 10 papers
Netherlands: 9 papers



DISCUSSION

Advantages of using UPPAAL

- Graphical user interface.
- Simplicity in model creation.
- Powerful simulator and debugger.
- A powerful verification engine to deliver an absolute guarantee of safety.
- Automatic and thorough verification.

Guidelines for selecting the appropriate UPPAAL variant

Use Case/Domain	Recommended Version	Key Features Needed	Notes
Formal verification of real-time systems	Classic	Timed automata, reachability analysis, exhaustive model checking, safety and liveness properties	Ideal for protocol verification, embedded systems, and communication systems
Systems with stochastic behavior or uncertainty	SMC	Statistical model checking, probability evaluation, simulation	Suitable for energy-aware systems, battery analysis, and performance evaluation under uncertainty
Adaptive control in smart systems; resource-aware decision-making; energy-aware scheduling	Stratego	Strategy synthesis, cost optimization, machine learning integration	Suitable for systems requiring optimal and adaptable strategies; leverages reinforcement learning to improve control performance
Adversarial control; planning under uncertainty	TIGA	Timed game automata, strategy synthesis, controller generation	Useful in scheduling, autonomous systems, and human–robot interaction
Real-time scheduling; performance evaluation of timed systems; cost-optimal planning	CORA	Cost variables, optimal scheduling, extended priced timed automata	Ideal for scenarios where timing and resource consumption must be optimized simultaneously

Open challenges

- Limited support for a hierarchy of states.
- No support for shared memory.
- Big machine power needed to validate the given requirements.
- Could provide a better user experience.
- System variables cannot change via external interactions with the environment, although some other model checkers enable it, but in these cases, the environment must also be modeled.

CONCLUSIONS

Summary & Key Takeaways

- We have conducted a systematic review of 188 publications (2022–2023) on the Uppaal tool.
- Uppaal SMC and Stratego are the most commonly used versions.
- The distribution of works between conference papers and research papers is almost equal.
- Research is geographically diverse, with strong activity in Southeast Asia, Europe, and the Americas.
- The choice of the Uppaal tool often results from its ease of use and high efficiency. These aspects are often emphasized in various application areas, since Uppaal is frequently used by non-engineers. This aligns with the original design goals of Uppaal, prioritizing user accessibility and computational performance.
- Findings offer insights for both users and developers of Uppaal.

DZIĘKUJĘ ZA UWAGĘ

WIĘCEJ SZCZEGÓŁÓW:

sensors

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A SYSTEMATIC REVIEW ON THE APPLICATIONS OF UPPAAL SENSORS. 2025; 25(11):3484