Two-Automaton Emptiness Check in Spot

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Two-Automaton Emptiness Check in Spot

1. Spot and the model checking toolchain
2. Existing implementations
3. New implementation
4. Conclusion

Spot and the model checking toolchain

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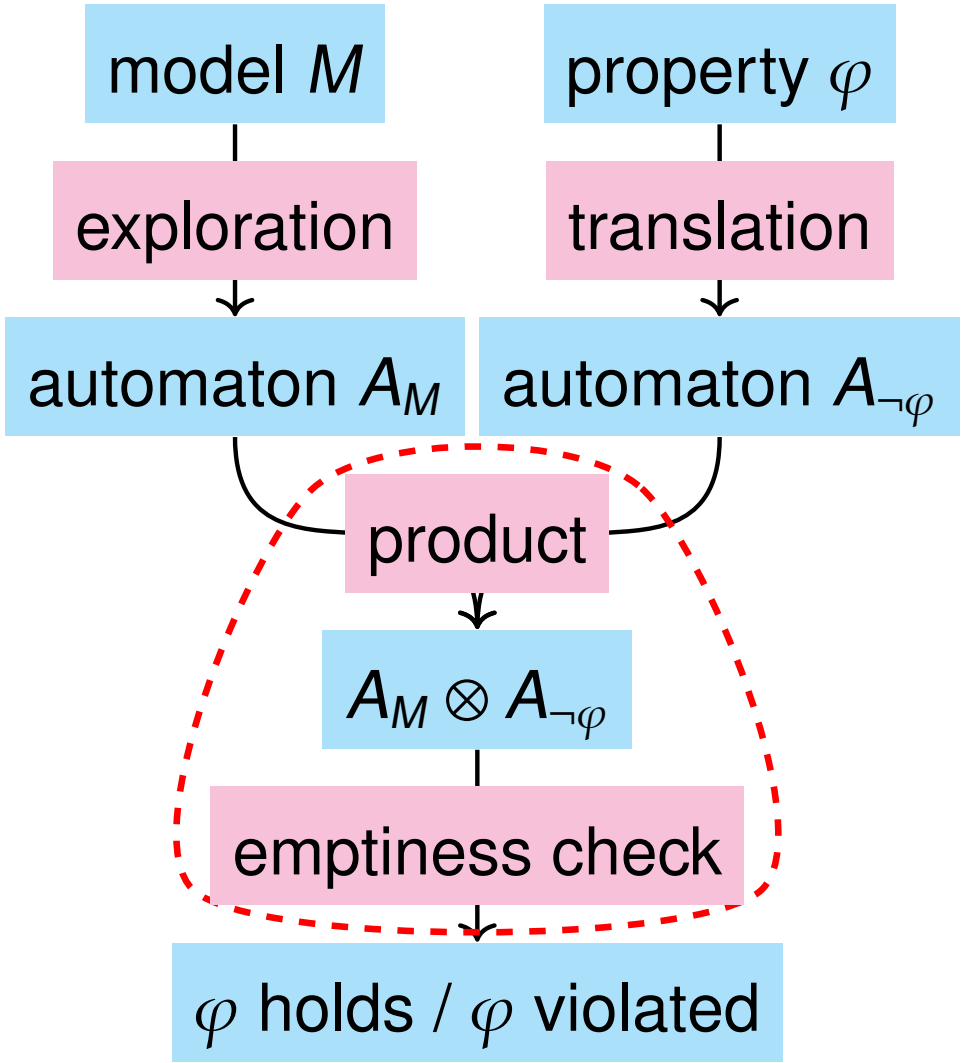
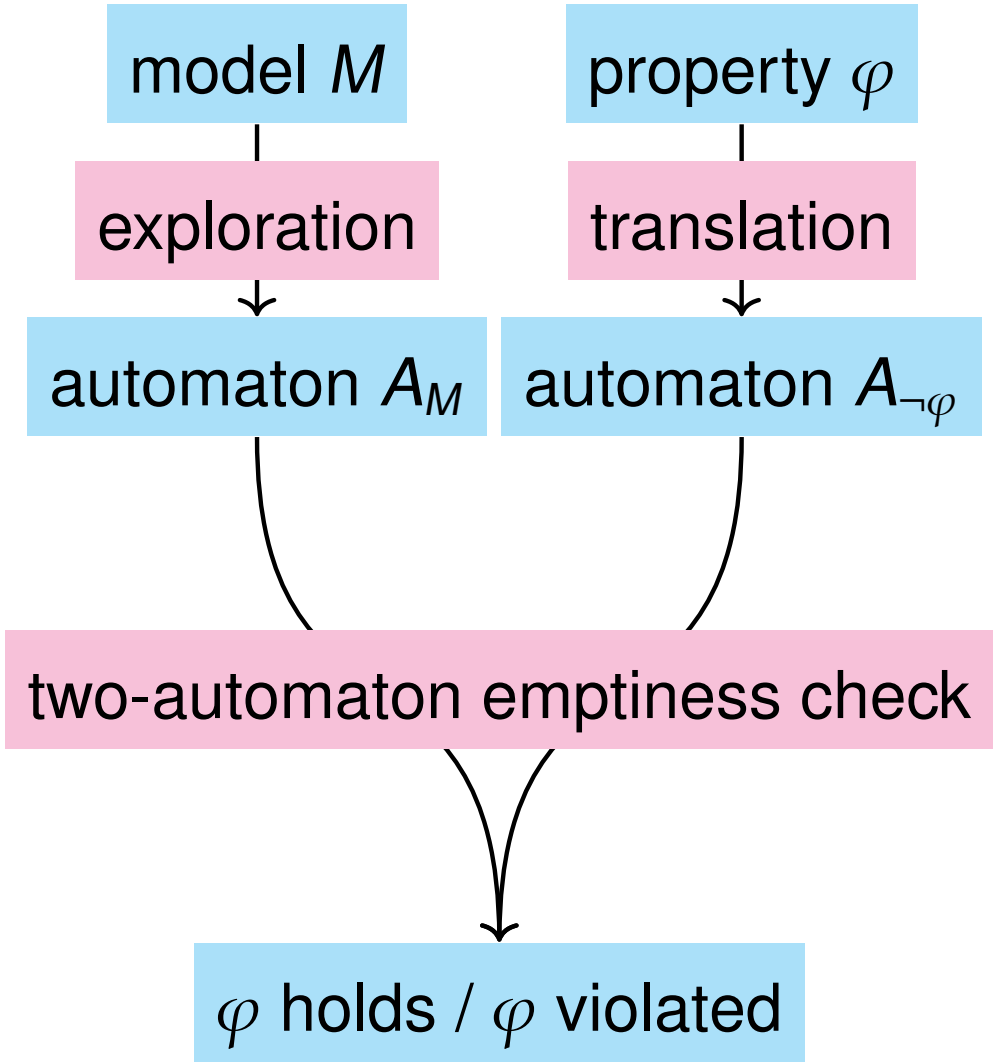
Spot

- C++ library [1]
- ω-automata for model checking
- on-the-fly and explicit automata
- Kripke structures, strength decomposition [2] …

The model checking toolchain



The model checking toolchain



Existing implementations

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Existing code

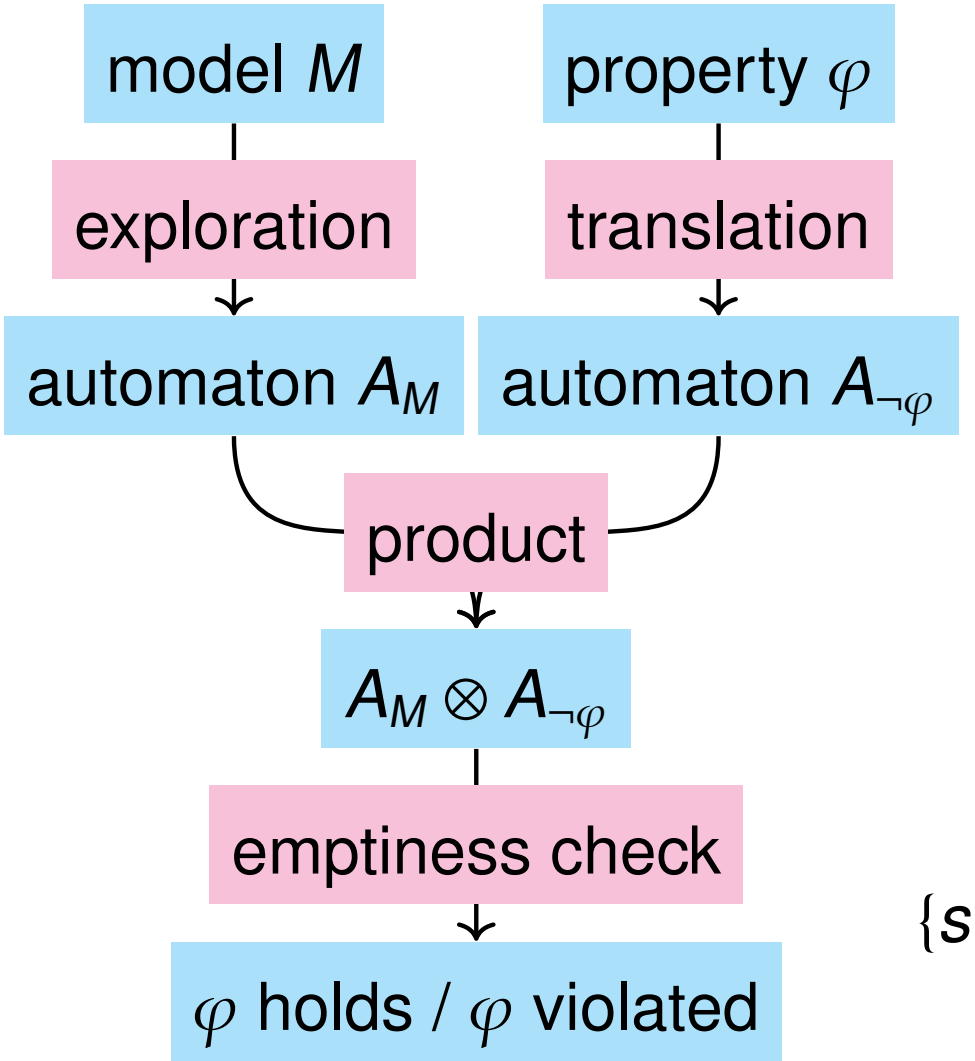
In `twa::intersects`:

```
return !otf_product(a, b)->is_empty();
```

`otf_product` on-the-fly product, uses on-the-fly interface, returns an on-the-fly automaton, optimized on Kripke structures,

`is_empty` Couvreur [3], uses on-the-fly or explicit interface, optimized on expliciteness and strength.

Existing code



$\{otf, kripke\}$

$\{otf, explicit\}$
$\times$
$\{strong, weak, terminal\}$

New implementation

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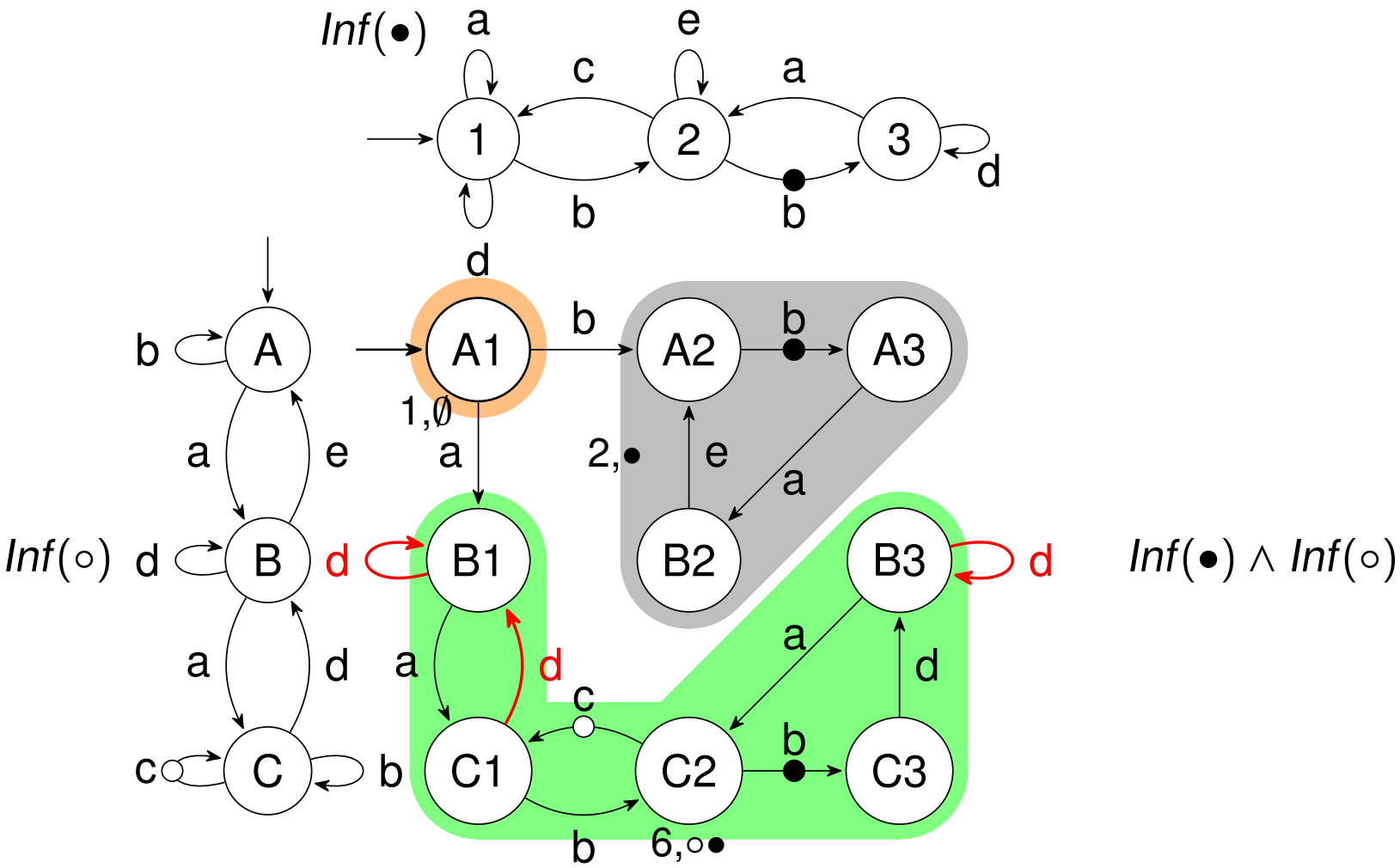
Unrolling of the algorithm



Optimizations

Explicit automata:

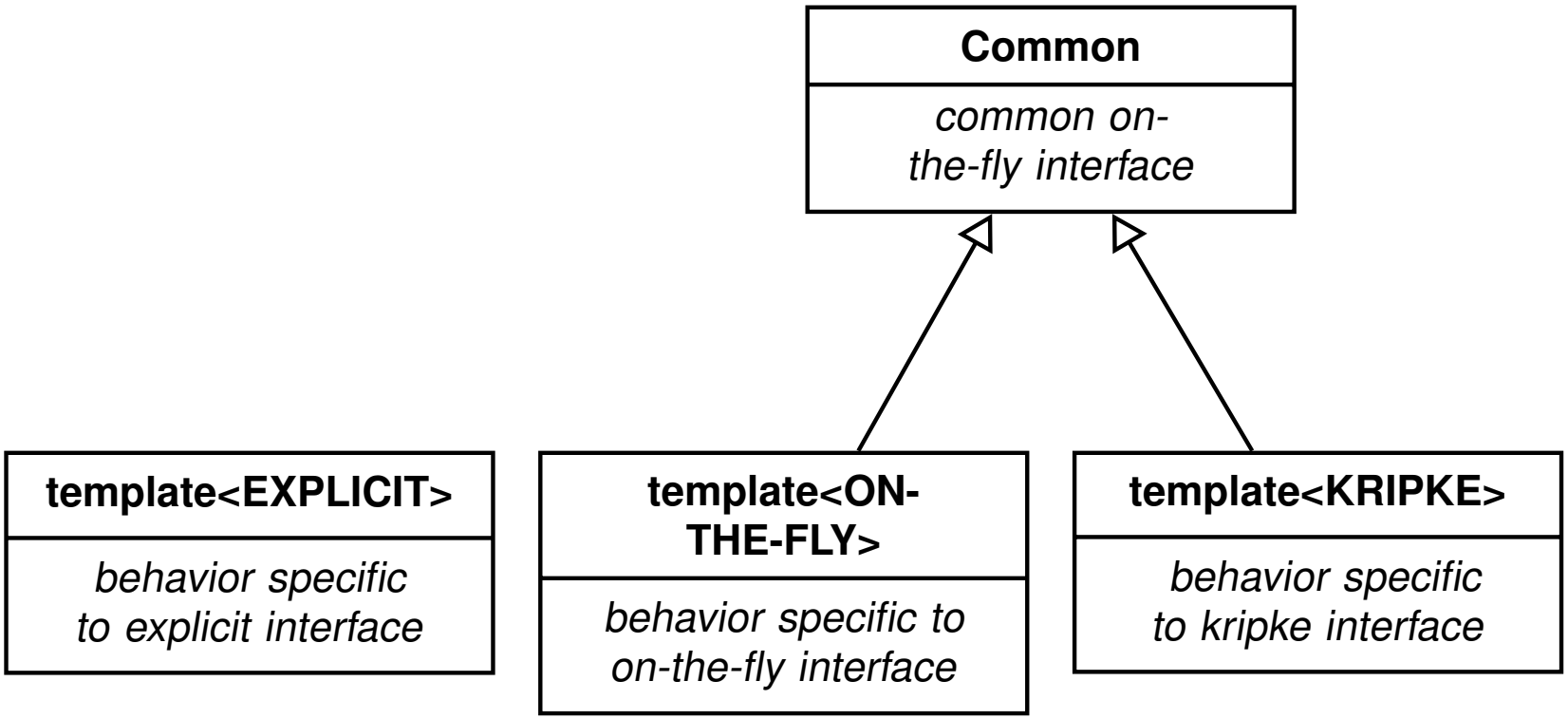
- template specialization of iterator and states
- reproduce behavior of on-the-fly iterators with explicit interface
- same with states
- improvements in structure size and method calls

Optimizations

Kripke and Fair-Kripke structures:

- very similar to on-the-fly
- “No dynamic dispatch!”
- solution: inheritance of common behavior in templates
- improvements in method calls

Optimizations



Optimizations

Strength of SCCs:

- lighter structures
- what you store is not what you use
- code uses STRONG-STRONG, structures stores STRONG-STRONG, WEAK-STRONG, or is unused
- conversions lose data, operations gain data
- improvements in structure size and usage

Optimizations

$$\{explicit, on\text{-}the\text{-}fly, kripke\}$$
$$\times$$
$$\{explicit, on\text{-}the\text{-}fly\}$$
$$\times$$
$$\{strong - strong, weak - strong, weak - weak\}$$

18 instances

Conclusion

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Benchmarks

- Explicitness:
  - 50 pairs
  - 200 states
  - random combination of 16 acceptance sets
  - 10 boolean variables

  two-automaton emptiness check: 1595s
  `otf_product` + `is_empty`: 1750s
- Strength: no significant result
- Kripke: not yet

Conclusion

What remains to do:

- return counter example

Questions?


Alexandre Duret-Lutz, Alexandre Lewkowicz, Amaury Fauchille, Thibaud Michaud, Etienne Renault, and Laurent Xu.
Spot 2.0 — a framework for LTL and ω-automata manipulation.
In *Proceedings of the 14th International Symposium on Automated Technology for Verification and Analysis (ATVA'16)*, volume 9938 of *Lecture Notes in Computer Science*, pages 122–129. Springer, October 2016.


Etienne Renault, Alexandre Duret-Lutz, Fabrice Kordon, and Denis Poitrenaud.
Strength-based decomposition of the property Büchi automaton for faster model checking.
In Nir Piterman and Scott A. Smolka, editors, *Proceedings of the 19th International Conference on Tools and Algorithms for the Construction and Analysis of Systems (TACAS'13)*, volume 7795 of

Lecture Notes in Computer Science, pages 580–593. Springer, March 2013.

Jean-Michel Couvreur.
On-the-fly verification of temporal logic.
In Jeannette M. Wing, Jim Woodcock, and Jim Davies, editors, *Proceedings of the World Congress on Formal Methods in the Development of Computing Systems (FM'99)*, volume 1708 of *Lecture Notes in Computer Science*, pages 253–271, Toulouse, France, September 1999. Springer-Verlag.