Symmetric Cryptanalysis SotA and Future:

Towards a Generalization of Cryptanalysis Techniques

María Naya-Plasencia

ERC SoBaSyC

SKCAM

Symmetric-key Cryptanalysis Automation and Modelling

We have seen in the morning:

- Most popular existing tools for automated cryptanalysis.

We will see in the afternoon:

- Recent results and open problems contributing to cryptanalysis automation

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Now:

- We will see the context and the gap between both parts (not technical talk).

Symmetric Cryptography

Essential to secure communications efficiently: widely used.

Two main tasks:

- Design symmetric primitives (answering needs).
- Cryptanalysis, foundation of trust:
  applying known attacks to new primitives & discovering new attacks.

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What is the problem?

In current cryptanalysis context:

- Many serious drawbacks
- Impossible to efficiently check if a primitive resists all known attack techniques

$\Longrightarrow$ Impacts confidence levels for symmetric primitives.

Symmetric Cryptanalysis Context

Many recent competitions for new standards motivated by new needs:

- 200+ new symmetric primitives designs.
- Huge amount of new ad hoc cryptanalysis results (known and new families).

Paradox: urgency of results does not allow to fully understand them – waste of time.

Main Drawbacks Generated by the Context

Drawback 1:
Low security understanding of new designs, sometimes broken by known techniques.

Drawback 2:
Some published attacks incorrect or non-optimal.

Drawback 3:
Many techniques re-discovered or/and renamed, and not reaching full potential.

Algorithmic Approach to Cryptanalysis

A bit chaotic, sometimes better to take a step back!

First objective

Generic algorithmic framework capturing all variants of known cryptanalysis techniques

Why is it hard?

Ad hoc attacks against specific primitives:

- relevant generalization and formalism?
- underlying algorithmic problems?

Final ideal objective

Include all this algorithms in an Open Cryptanalysis Platform (see Thomas's talk)
$\Longrightarrow$ the reference security benchmark for symmetric primitives.

About Existing Tools

Very nice and important effort! But,

- Often, tools dedicated to concrete attacks or even a concrete step of the attack, or on concrete ciphers. Most generalizations on isolated steps or include heuristics getting away from optimality.

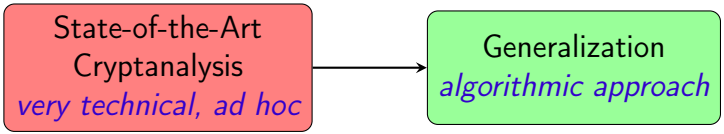
- Because of the chaotic situation, many do not include most existing improvements in the litterature (very difficult).

- Often hard to use: not systematically used by designers when proposing new designs in rationalle (see Maria E's talk for this).

From Ad Hoc to Generic, from Approximative to Accurate

State-of-the-Art
Cryptanalysis
very technical, ad hoc

From Ad Hoc to Generic, from Approximative to Accurate



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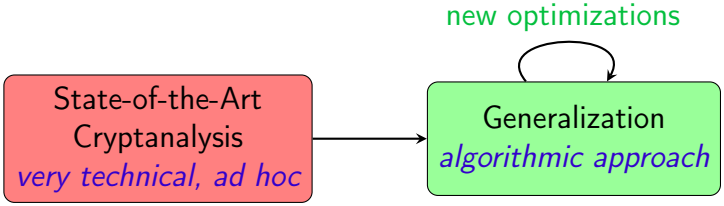

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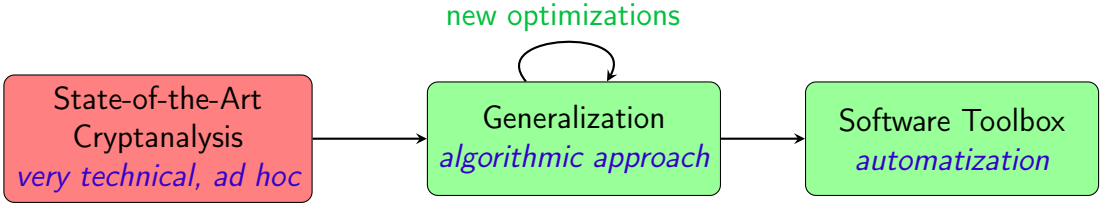

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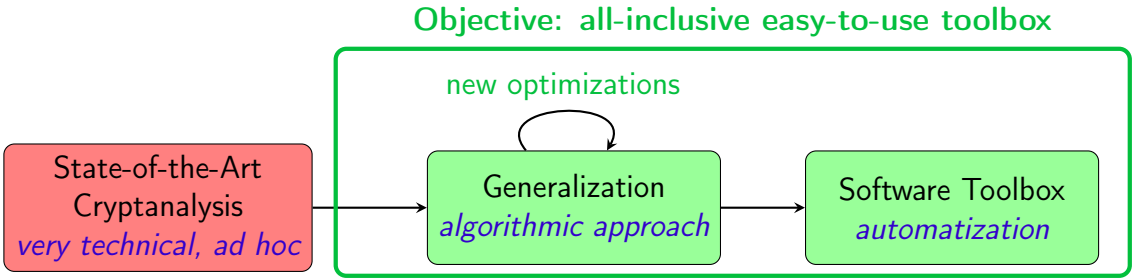

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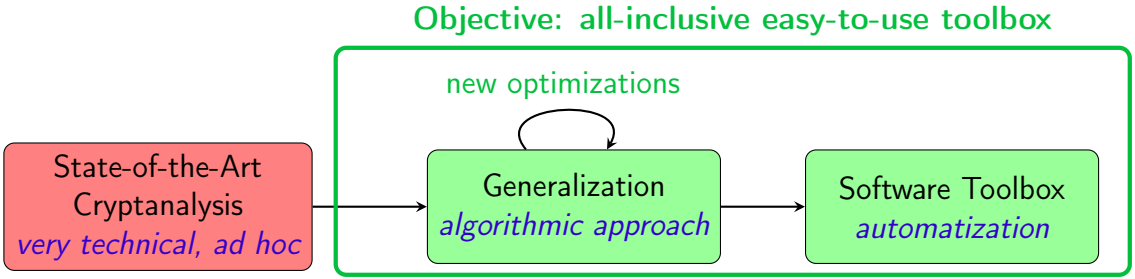
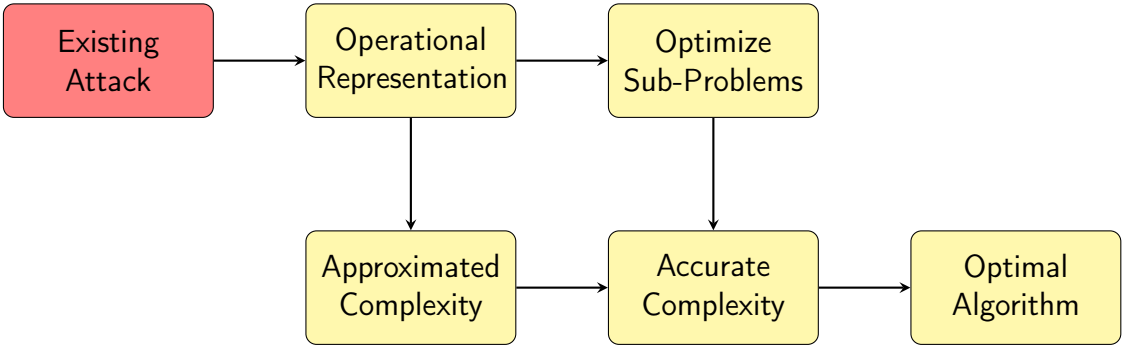


Many preliminary steps already done in these directions, but many left!

The Generalization Step



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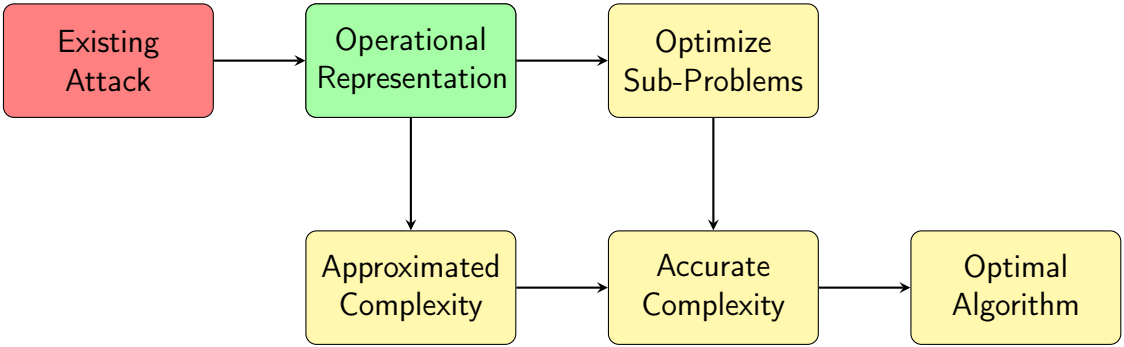

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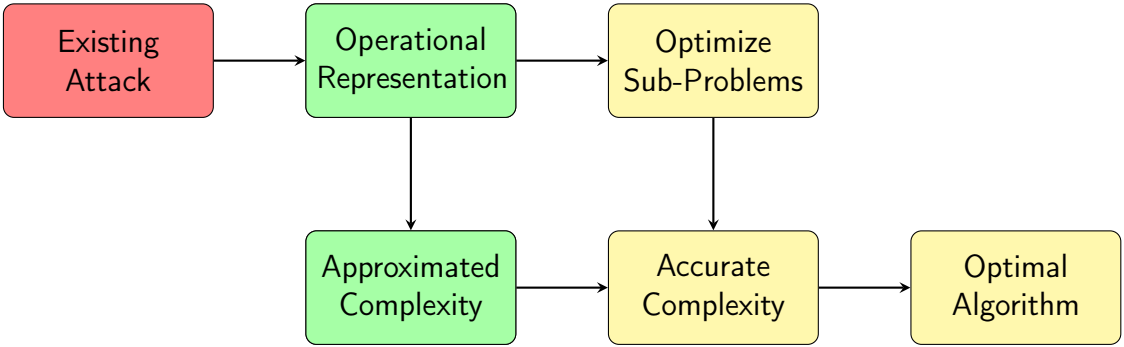

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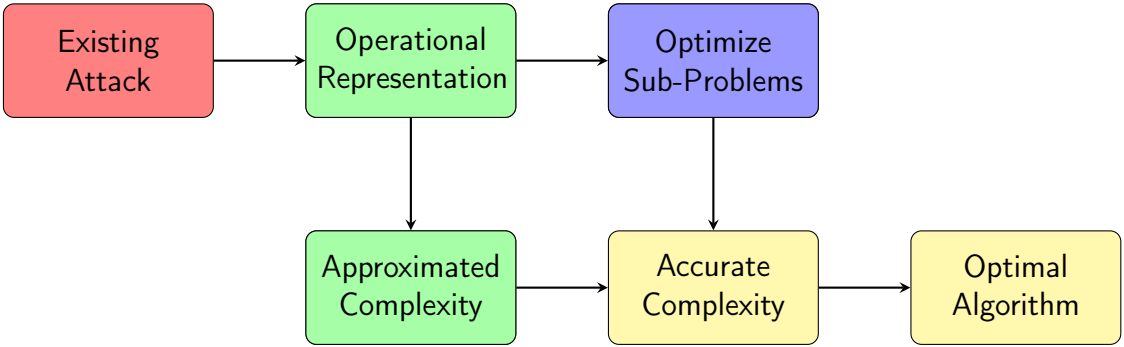

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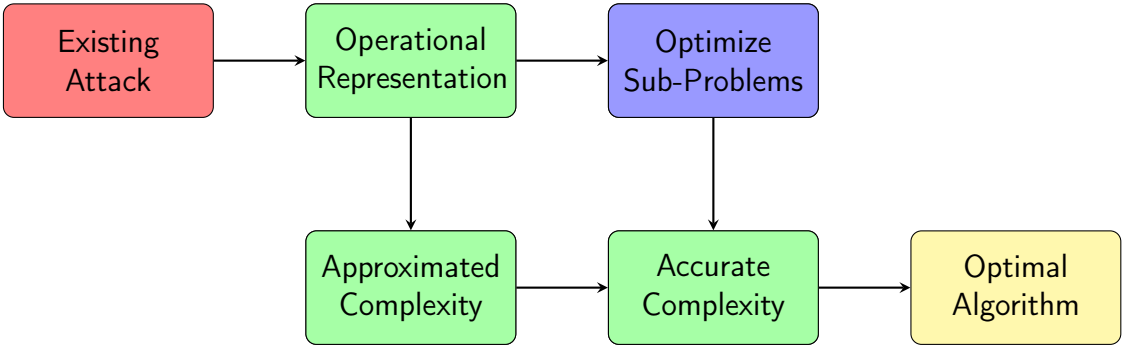

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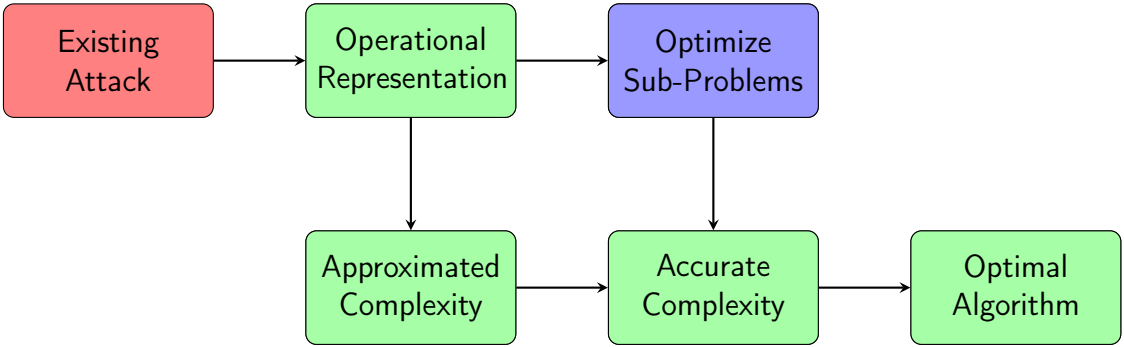
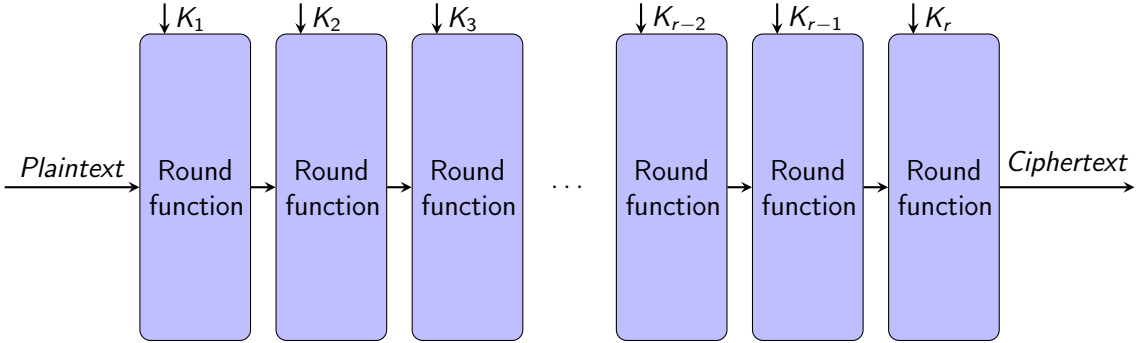


Example Case: Generalizing Differential Attacks [BS90]

Symmetric primitives are iterative. Attack: recover the secret faster than brute force.



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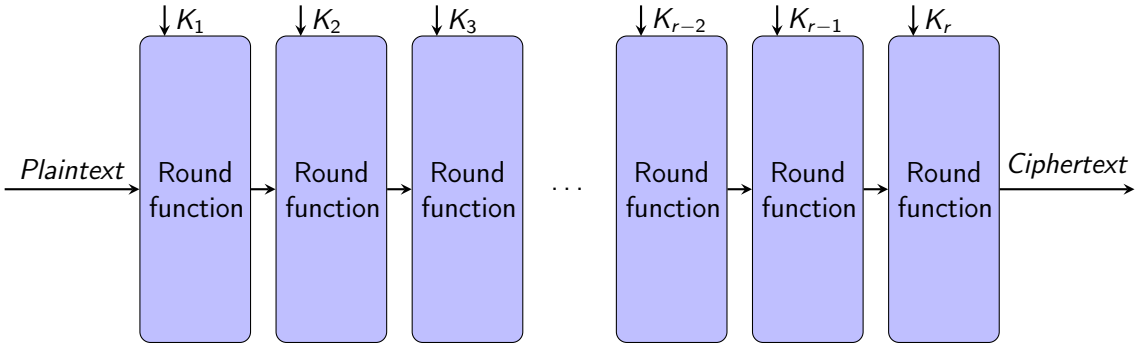
Finding attacks is a tedious procedure, often in 2 separate (but non-independent) steps:



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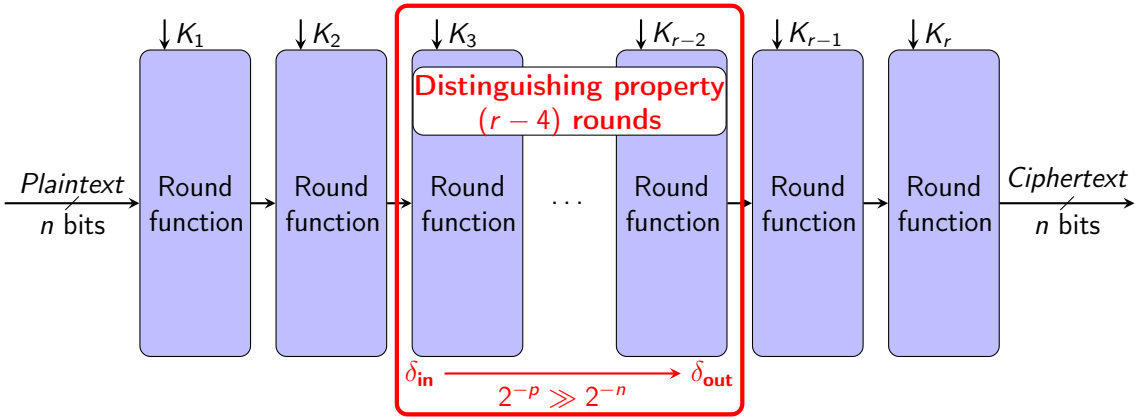

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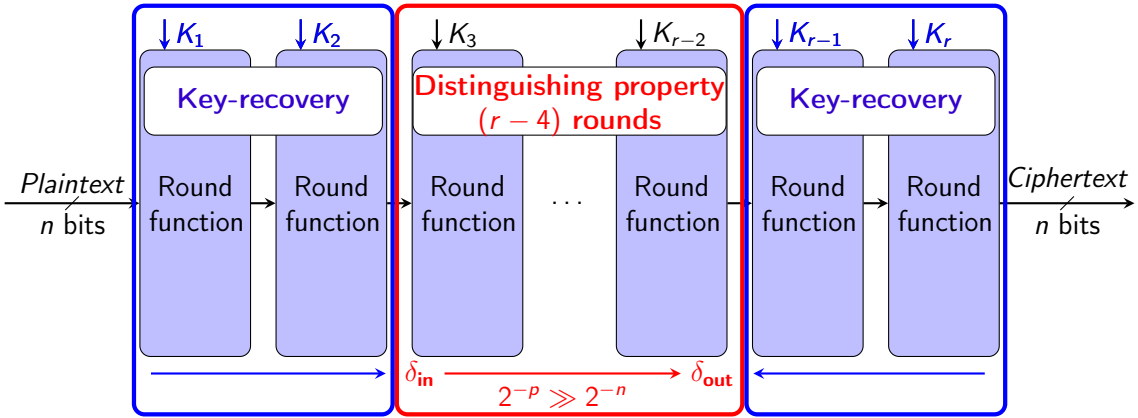
Finding attacks is a tedious procedure, often in 2 separate (but non-independent) steps:

1. Find a distinguishing property.
2. Find the optimal key-recovery.



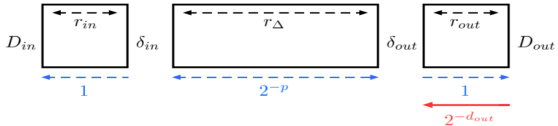
Existing Automation of (Differential) Attacks

- Finding a distinguisher:
  Some tools MILP, CP, SAT... find the best distinguisher for a given number of rounds (under some heuristics). See for instance Shaowei's talk.
- Finding the optimal key-recovery step:
  Tools for the best key-recovery step in concrete cases. See for instance Ling's talk.
- Finding the best overall attack (best distinguishers don't imply best attacks):
  Some tools partially include this with heuristics on the lower bound of the key-recovery (number of solutions). See for instance Hosein's talk this morning, or Patrick's talk on impossible differential attacks.

But an algorithm providing the best overall attacks? First generalization!

Ex: Generalize attacks? Start from a concrete attack.

1. Operational representation:



2.a Approximated complexity:

$$\mathcal{T} = \left(2^{p+1} + 2^{p+1}\frac{C_S}{C_E} + 2^{s+2d_{in}-1-n+d_{out}}\frac{C_{KR}}{C_E}\right)C_E.$$

2.b Optimize subproblems and include improvements.

Derive non-natural relevant parametters

3. More accurate complexity.
4. Repeat for other constructions: generalize and merge.
5. Put it all together -> towards an optimized and generalized algorithm to implement.

Interesting Tasks To Do

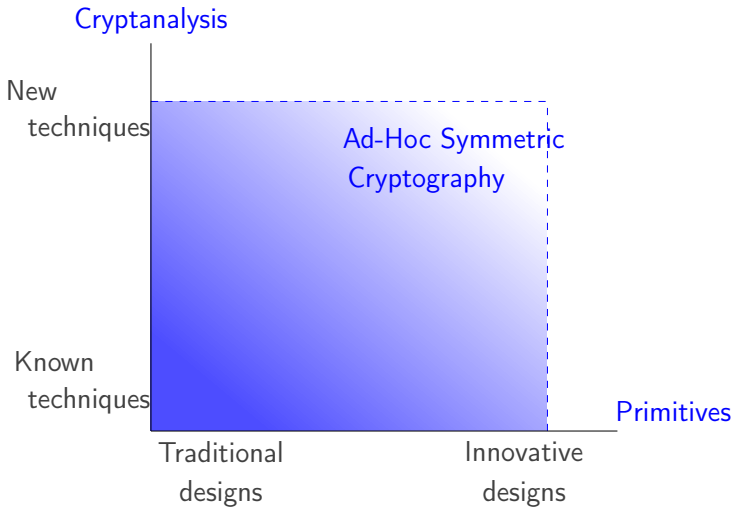
- Generalization steps representation and approximated complexity: have already been done for some families.
- Optimizing subproblems, including advanced variants, deriving more accurate complexities is more rare.

A lot of litterature to go through!

- In general, can be interesting to always take into account:
  - an "allowed precomputation parameter",
  - not to systematically cut steps at full rounds but consider partial rounds,
  - reusing more often gradual computations.

(Link to Hosein's talk.)

Different Scenarios



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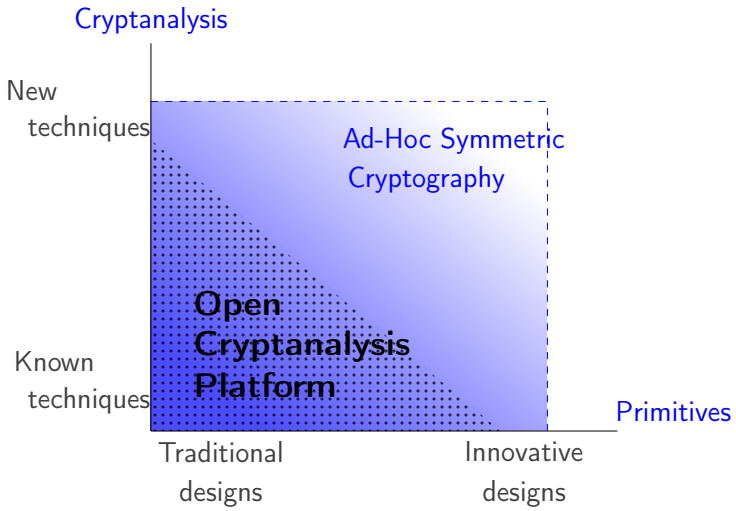

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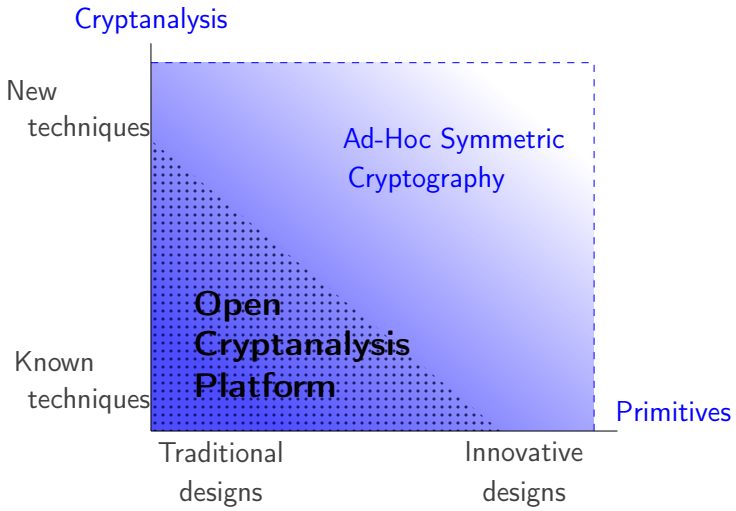

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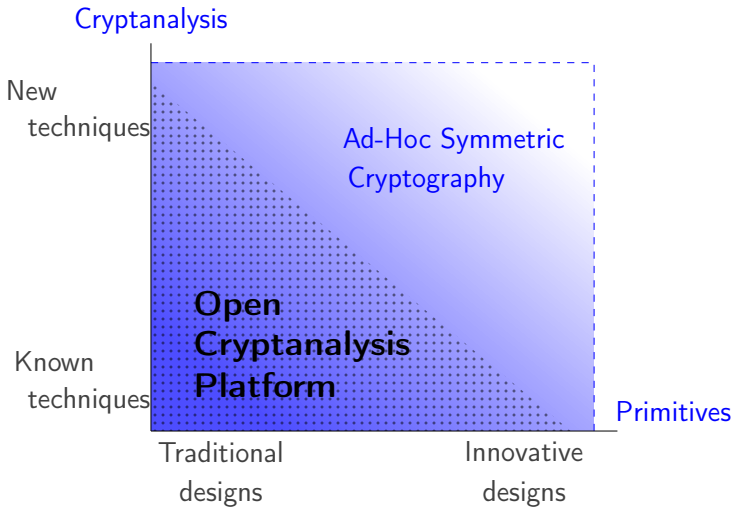

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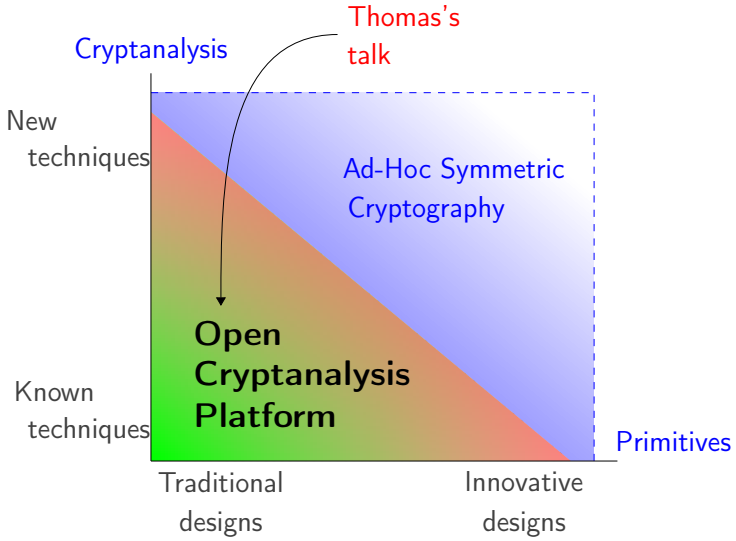

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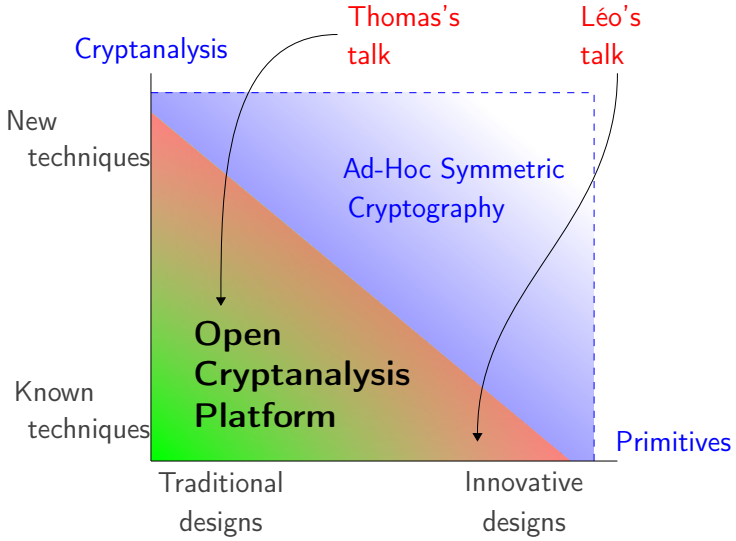

Conclusion and future

- We need to transform known symmetric cryptanalysis with an algorithmic formalism through generalisation.
- Long term goal (but we need to keep on working towards it now!): Reference benchmark for evaluating the resistance to known attacks.
- More time for new ad hoc results!
- Always new results, or more complicated to generalize: not everything will be included, but the toolbox will evolve.