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Implementing an Electronic Design Automation Tool for Cryptographic Hardware using Functional Languages

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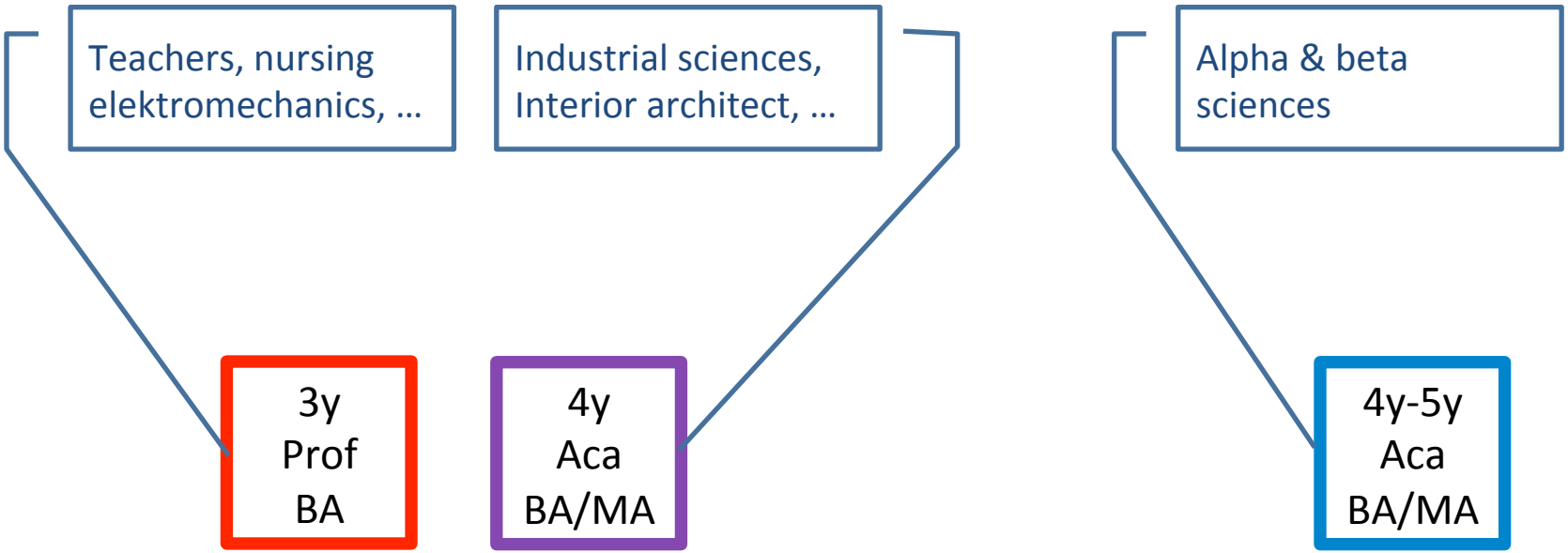
KHLim – KU Leuven

3 Trends in 1 Project Paper

- Belgian Landscape of Higher Education
- Progress in our research topic
- FP pervading common practice
  - F#
  - Lambda expressions in C#
  - Java FX
  - Java: Scala & Closure
  - …

Higher Education in Flanders (B)

Originally ternary (French system)



University colleges
Education

Universities
Research & education

Learning a job

Academic level

Since Bologna: moving to binary

University colleges
Education

Universities
Research & education

Learning
a job

Academic
level

Consequences

- **More research**
  - From applied to more fundamental
- **More cooperation**

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Higher Education in Flanders (B)

Teaming up locally

Nele Mentens

PhD in 2007

"Secure and Efficient Coprocessor Design for Cryptographic Applications on FPGAs"

Me

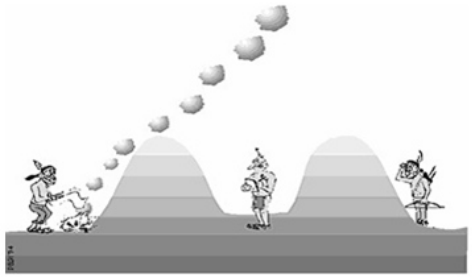
PhD in 2001

"Visto: A Declarative Methodology for Graphical User Interfaces, based on Haskell"

Our research focus: crypto

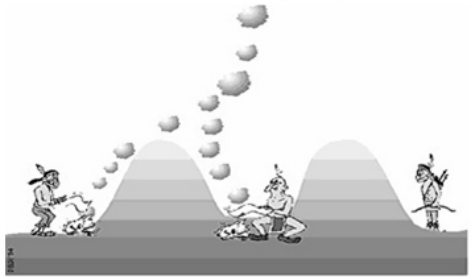
Principles

Data confidentiality

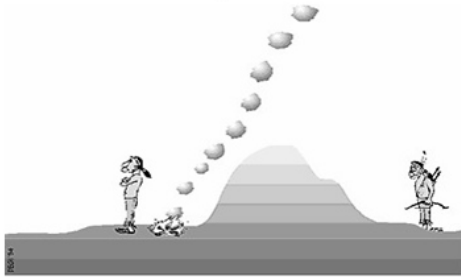


User authentication

Data integrity



Non-repudiation



Applications

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What's the problem with crypto?

A developer's view

Developing a cool new device

Adding crypto

What makes crypto difficult?

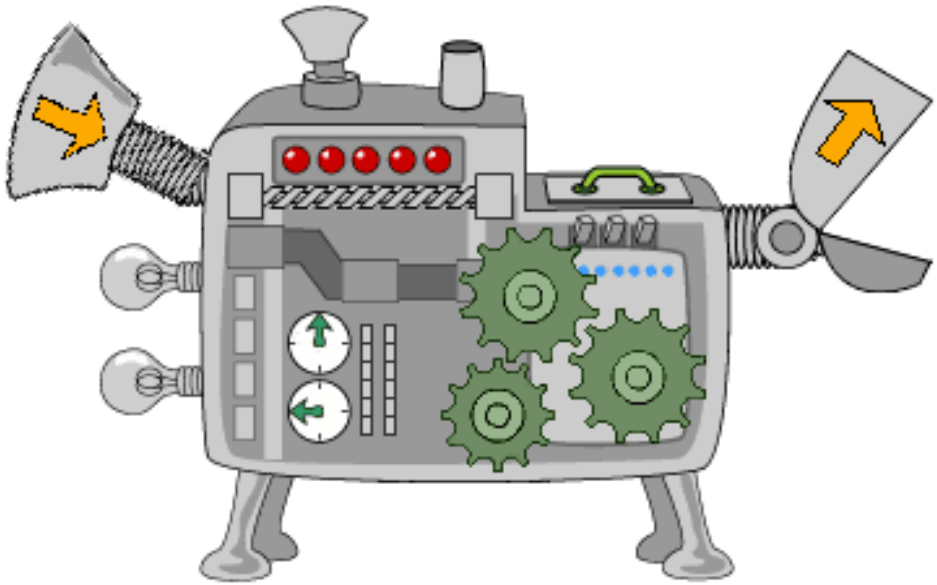
- Complex math
- Side channel attacks
  - Both destructive and non-destructive methods
  - A business on its own
- Limited resources (on FPGA)
  - Most surface is reserved for actual app
  - And/or only small time delay is allowed

The (“a”) solution

- Electronic Design Automation Tool

User

- selects crypto-algorithm
- defines implementation platform
- imposes time/space/security constraints



Machine **outputs**:

- VHDL
- Verilog
- HW/SW co-design

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Important considerations

Electronic Design **Automation tool**

- black box
- easy to use
- implemented in Lava / Haskell
- no programming skills needed

Functional programming pervading

Teaming up regionally

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Research concentrates on

- *cryptographic algorithms and protocols,*
- *development of security architectures for information and communication systems*
- *the development of security mechanisms for embedded systems.*

Main themes of study are in the fields of

- *declarative languages,*
- *machine learning,*
- *data mining,*
- *and knowledge representation.*

Project plan

Bottom up approach *"Think locally, act globally"*

1. Large number library
   - (Brute force) design exploration
2. Crypto generator for hardware
   - Entire core instead of functions
   - Algorithms are supplied: no programming needed
   - Countermeasures against side channels attacks
3. Extending tot HW/SW co-design

Step 1: preliminary tool

Design space exploration by combining

- different data path widths
- different architectures for +, *, …
- different finite state encodings
- optimisations towards space or speed

CREA-project of KU Leuven

- Creative, high risk projects

Lava: DSL in Haskell

```
halfadder (a,b) = (sum, carry)
  where
        sum = xor2(a,b)
        carry = and2(a,b)

halfadder' (a, b)  = ( a <#> b, a <&> b)


rippleCarryAdder (carryIn, (as, bs)) = (sum, carryOut)
   where
        (sum, carryOut) = row fullAdder (carryIn, zipp (as, bs))
```

It works!

Montgomery algorithm for multiplying 2^m-bit field numbers on a n-bit data path.

SOS

Separate operand scanning

CIOS

Coarsely integrated operand scanning

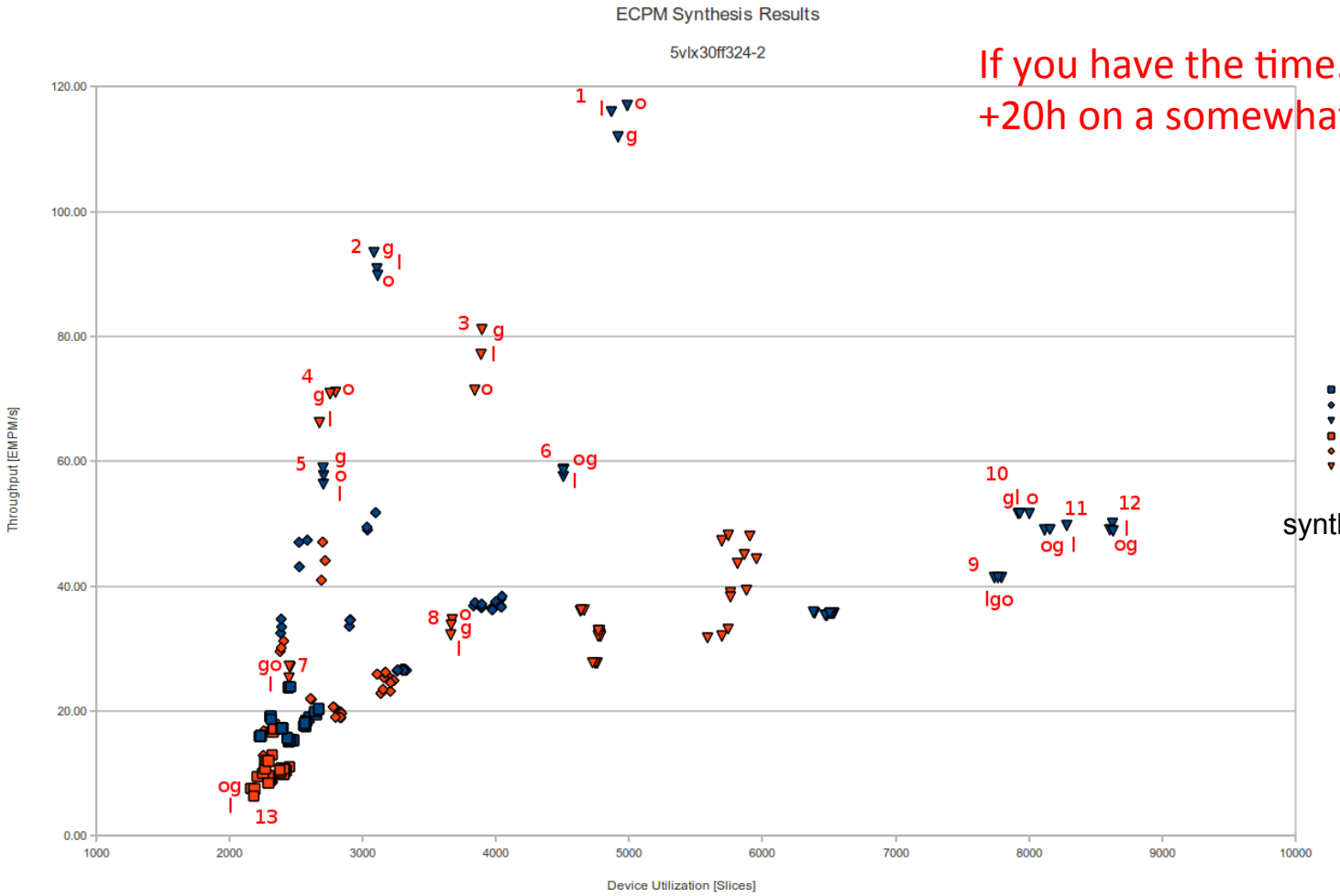
FIOS

Finely integrated operand scanning

FIPS

Finely integrated product scanning

It works!



If you have the time…
+20h on a somewhat decent PC

synthMMM [256]
[8, 16, 32, 64]
[CIOS, FIOS]
[FullProdCSAARCA,
FullProdCSAACSE,
FullProdCSAASklansky,
FullProdCSAAVhdlAdd,
VhdlMult]
[NetList, Vhdl]
[Xst.Area, Xst.Speed]
[EncOneHot, EncGray]

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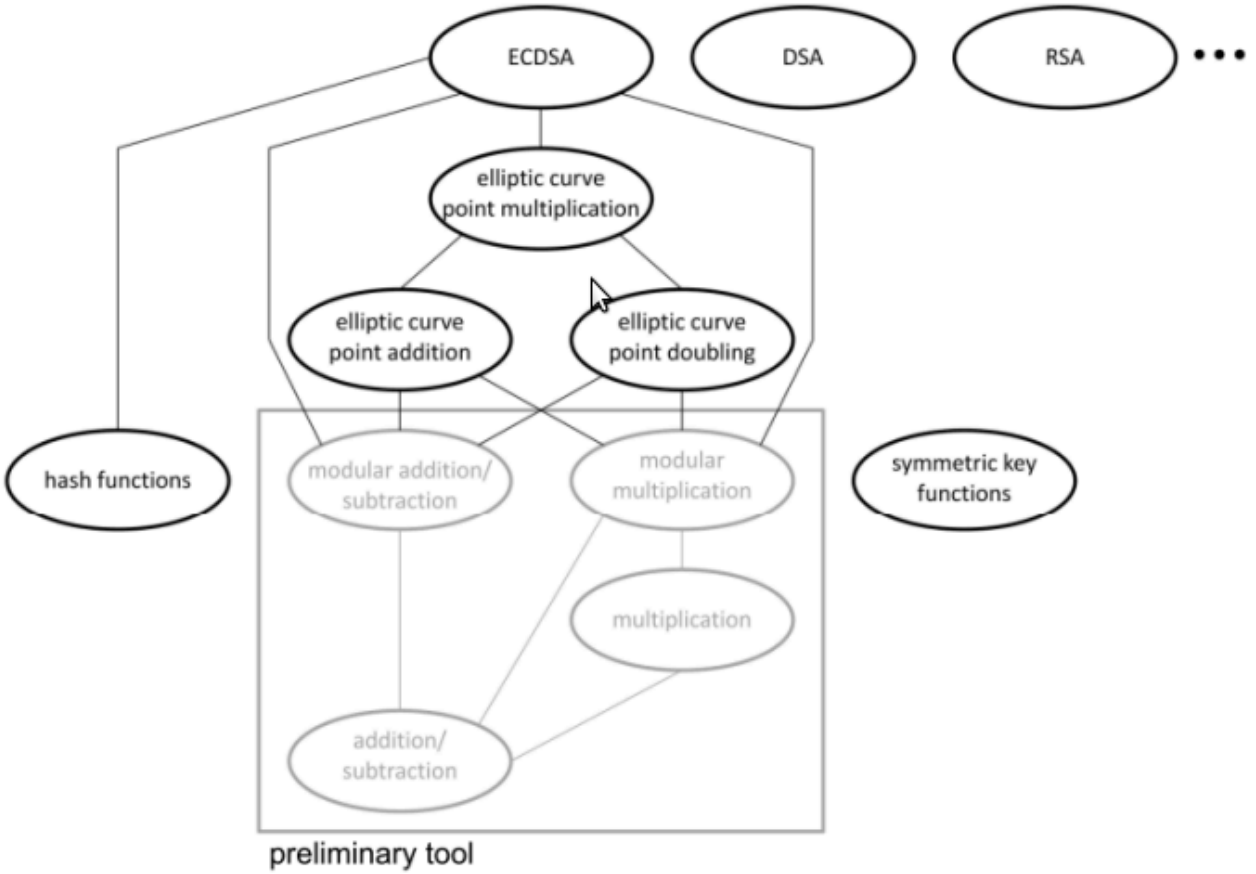
Making it faster

- Pruning the tree
- Intelligent search algorithms

More capable



Projected algorithmic and architectural expansion of the preliminary tool.

Making it more clever

- Machine learning
- (Monadic) Constraint Programming

Making crypto cores

- Current and future security algorithms
- Counter measures against side channel attacks incorporated in all (steps of all) designs

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Expanding the scope

- HW/SW co-design

Teaming up globally

- Expanding framework to other domains
- *Later…*

Conclusion

- Combination of different research fields/groups with FP as the glue inbetween
  - Our scope broadens from FP to declarative/logic programming with applications in crypto and hardware
- FP is not visible to the end user, but is of vital importance
  - Builds on the success of applying FP in hardware design, but removes the stress of re-educating VHDL-designers

Questions?

The end.

Or actually the beginning.