UNIVERSITY OF TARTU
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Exploring integration complexity of different multi-national eID authentication solutions in the EU private sector

Master's Thesis (24 ECTS)

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May Flower, PhD

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Abstract:
Many interpreting program languages are dynamically typed, such as Visual Basic or Python. As a result, it is easy to write programs that crash due to mismatches of provided and expected data types. One possible solution to this problem is automatic type derivation during compilation. In this work, we consider study how to detect type errors in the WHITESPACE language by using fourth order logic formulae as annotations. The main result of this thesis is a new triple-exponential type inference algorithm for the fourth order logic formulae. This is a significant advancement as the question whether there exists such an algorithm was an open question. All previous attempts to solve the problem lead lead to logical inconsistencies or required tedious user interaction in terms of interpretative dance. Although the resulting algorithm is slightly inefficient, it can be used to detect obscure programming bugs in the WHITESPACE language. The latter significantly improves productivity. Our practical experiments showed that productivity is comparable to average Java programmer. From a theoretical viewpoint, the result is only a small advancement in rigorous treatment of higher order logic formulae. The results obtained by us do not generalise to formulae with the fifth or higher order.

Keywords:

List of keywords

CERCS:

CERCS code and name: `https://www.etis.ee/Portal/Classifiers/Details/d3717f7b-bec8-4cd9-8ea4-c89cd56ca46e`

Tüübituletus neljandat järku loogikavalemitele

Lühikokkuvõte:

One or two sentences providing a basic introduction to the field, comprehensible to a scientist in any discipline.

Two to three sentences of more detailed background, comprehensible to scientists in related disciplines.

One sentence clearly stating the general problem being addressed by this particular study.

One sentence summarising the main result (with the words “here we show´´ or their equivalent).

Two or three sentences explaining what the main result reveals in direct comparison to what was thought to be the case previously, or how the main result adds to previous knowledge.

One or two sentences to put the results into a more general context.

Two or three sentences to provide a broader perspective, readily comprehensible to a scientist in any discipline, may be included in the first paragraph if the editor considers that the accessibility of the paper is significantly enhanced by their inclusion.

Võtmesõnad:

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Contents

Unsolved issues

1 Introduction

1.1 Motivation

With the emergence of COVID-19, work from home has rapidly grown in popularity. It has been especially noticeable in the IT industry. This phenomenon has led some businesses to transition to operate fully remote [1], allowing for potential customers, clients, and employees to operate with the companies' IT systems from all around the globe.

Identity verification is a significant roadblock when establishing a remote work policy. In some managerial businesses, such as logistics, it is essential to assure the authenticity of persons signing in to perform their duties. Traditionally, as work was always on-premises, it was easy to verify the identity with the help of an ID Card or equivalent and physical verification. With the constraints of operations being fully remote, companies can no longer perform such a check.

Establishing identity online for potential employees and clients is not the only use case for digital identity. Organizations such as the British Council employ privacy undermining practices. They require their customers to submit a photocopy of their identity document for verification purposes [2]. This process is a significant privacy concern since anyone could replicate the uploaded document. Having no agency over their documents is of great concern for the end-users, and they would be reluctant to use the company services. Replacing the document upload with a digital signature check is a more secure and trustworthy way of performing business.

After the EU introduced the eIDAS regulation, an alternative method for identity verification became available. All EU member states are mandated to implement an eID solution in their country and recognize other countries' eID solutions [3]. Each eID solution comes with an identity certificate and means to prove it by signing a challenge via public-key cryptography. Because of this regulation, it is now possible to obtain a persons' legal identity with trustworthy means.

Particular risks exist that businesses must be aware of before integrating an eID authentication service. There are no comprehensive resources outlining the obstacles and costs of implementing eID authentication in the private sector. Lack of information makes it difficult to assess risks and estimate the resources required [?]. Unknown risks are an excellent deterrent for innovation and make companies reluctant to use new technologies. Proper research into this subject may lead companies to take risks associated with implementation and kickstart the mainstream adoption of eIDs in the private sector.

Cite

1.2 Research Problem

The main goal of the thesis is to investigate if the advantages provided by eIDs are sufficient to warrant adoption in the free market and to shine a light on the costs associated with implementation. From this goal, the extracted research question is as follows:

What is the best eID authentication option available for an Estonian EU targeting enterprise for use in their Web-based Single Sign-On (SSO)?

Maybe it would be good to change to "is the market ready"

The research question can be refined further into additional sub-questions:

- What advantages do eIDs provide?
- What technological risks companies must address to implement the solution?
- What privacy considerations must companies take when processing user data?
- What are the categories of eID authentication solutions

QESD vs. middleware

- What are the different eID authentication options available to Estonia's private sector?
  - What risks the eID provider transfers?
  - What is the market reach (in countries) of a given solution?
  - Where are the weak points in the protocol used? How should a company assess them?

1.3 Scope and goal

Structure of work The document will consist of the following main chapters:

ISO standard to pick trust level for if companies even need it

What are different options in eIDAS, e.g. what is a QESSD

What are the differences between primary services and middlemen, advantages disadvantages

What are the weakpoints in the company structrue

What is the research model?

Findings about ID Card, Dokobit, and eeID

Non web-based SSO?

Ponder about the advantages of middleware pseudominization? Say instead of personal code you get some arbitrary ID that matters only in the system

2 Introduction

What is it in simple terms (title)?

Why should anyone care?

What was my contribution?

What you are doing in each section (a sentence or two per section)

Tip: if it's hard for you to start writing, then try to split it to smaller parts, e.g. if the title is "Type Inference for a Cryptographic Protocol Prover Tool" then the "What is it" can be divided into "what is type inference", "what is cryptographic protocol" and "what is the prover tool". These three can also be split to smaller parts etc.

3 Title of Section 2

Short description of what this section is about

3.1 Title of Subsection 1

Some text...

3.1.1 Title of Subsubsection 1

Some text...

3.1.2 Title of Subsubsection 2

Some text...

3.2 Title of Subsection 2

Rule: If you divide the text into subsections (or subsubsections) then there has to be at least two of them, otherwise do not create any.

Tip: You can also use paragraphs, e.g.

Type rules for integers. Some text ...

Type rules for rational numbers. Some text here too...

3.3 How to use references

Cross-references to figures, tables and other document elements. LaTeX internally numbers all kind of objects that have sequence numbers:

- chapters, sections, subsections;
- figures, tables, algorithms;
- equations, equation arrays.

To reference them automatically, you have to generate a label using `\label{some-name}` just after the object that has the number inside. Usually, labels of different objects are split into different namespaces by adding dedicated prefix, such as `sec:`, `fig:`. To use the corresponding reference, you must use command `\ref` or `\eqref`. For instance, we can reference this subsection by calling Section 3.3. Note that there should be a

nonbreakable space ~ between the name of the object and the reference so that they would not appear on different lines (does not work in Estonian).

Citations. Usually, you also want to reference articles, webpages, tools or programs or books. For that you should use citations and references. The system is similar to the cross-referencing system in LaTeX. For each reference you must assign a unique label. Again, there are many naming schemes for labels. However, as you have a short document anything works. To reference to a particular source you must use `\cite{label}` or `\cite[page]{label}`.

References themselves can be part of a LaTeX source file. For that you need to define a bibliography section. However, this approach is really uncommon. It is much more easier to use BibTeX to synthesise the right reference form for you. For that you must use two commands in the LaTeX source

- \bibliographystyle{alpha} or \bibliographystyle{plain}
- \bibliography{file-name}

The first command determines whether the references are numbered by letter-number combinations or by cryptic numbers. It is more common to use `alpha` style. The second command determines the file containing the bibliographic entries. The file should end with `bib` extension. Each reference there is in specific form. The simplest way to avoid all technicalities is to use graphical frontend Jabref (`http://jabref.sourceforge.net/`) to manage references. Another alternative is to use DBLP database of references and copy BibTeX entries directly form there.

The following paragraph shows how references can be used. Game-based proving is a way to analyse security of a cryptographic protocol [4, 5]. There are automatic provers, such as CertiCrypt [6] and ProVerif [7].

4 How to add figures and pictures to your thesis

Here are a few examples of how to add figures or pictures to your thesis (see Figures 1, 2, 3).

Rule: All the figures, tables and extras in the thesis have to be referred to somewhere in the text.

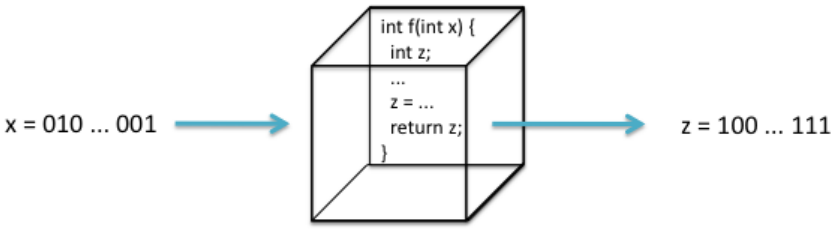


Figure 1. The title of the Figure.

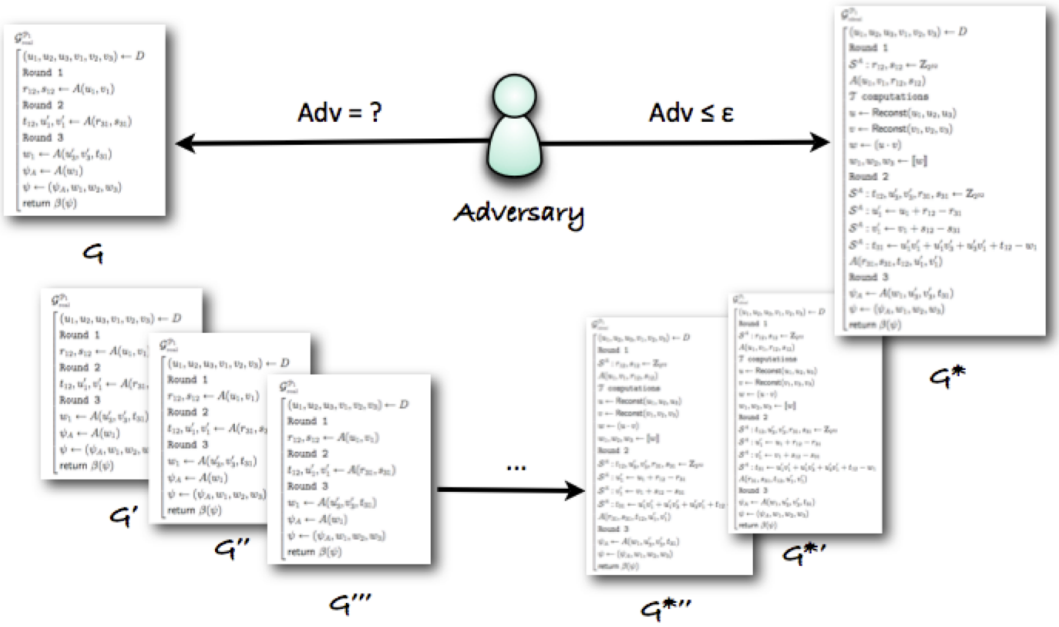


Figure 2. Refer if the figure is not yours [8].

Tip: If you add a screenshot then labeling the parts might help make the text more understandable (panel C vs bottom left part), e.g.

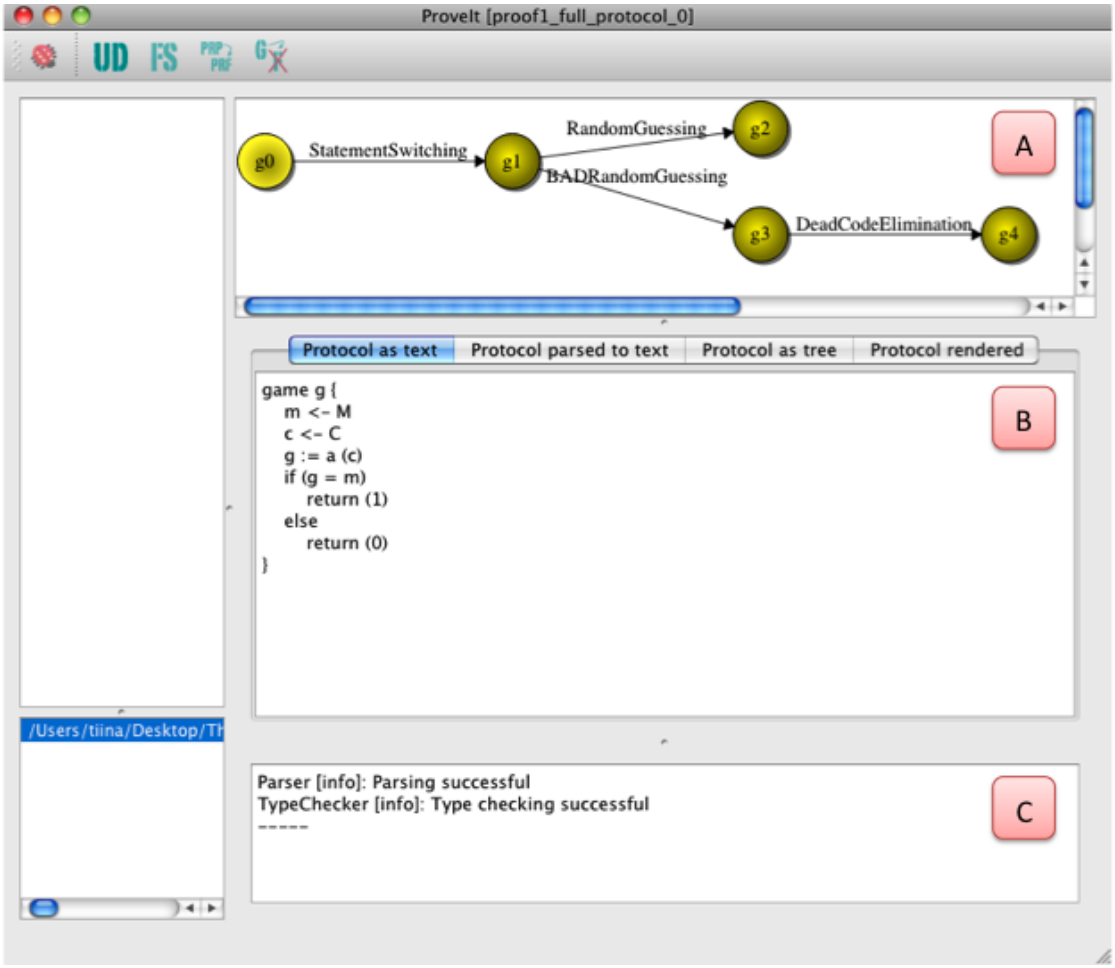
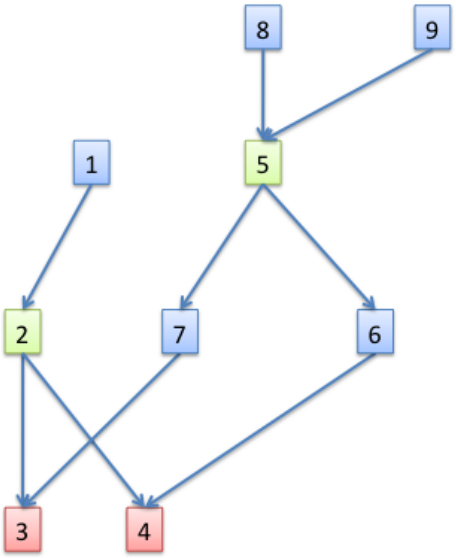


Figure 3. Screenshot of ProveIt.



Node	Decendants
1	2, 3, 4
2	3, 4
3	
4	
5	3, 4, 6, 7
6	4
7	3
8	3, 4, 5, 6, 7
9	3, 4, 5, 6, 7

Figure 4. Example how to put two figures parallel to each other.

Example: A screenshot of ProveIt can be seen on Figure 3. The user first enters the pseudocode of the initial game in panel B. ProveIt also keeps track of all the previous games showing the progress on a graph seen in panel A.

There are two figures side by side on Figure 4.

5 Other Ways to Represent Data

5.1 Tables

Table 1. Statements in the ProveIt language.

Statement	**Typeset Example**
assignment	$a := 5 + b$
uniform choice	$m \leftarrow M$
function signature	$f : K \times M \rightarrow L$

5.2 Lists

Numbered list example:

1. item one;
2. item two;
3. item three.

5.3 Math mode

Example:

$$a + b = c + d \tag{1}$$

Aligning:

$$\begin{aligned} a &= 5 \\ b + c &= a \\ a - 2 * 3 &= 5/4 \end{aligned}$$

Hint: Variables or equations in text are separated with $ sign, e.g. a, $x - y$.

Inference Rules

$$\text{addition}\frac{\Gamma \vdash x : T \qquad \Gamma \vdash y : T}{\Gamma \vdash x + y : T}$$

Bigger example:

$$\text{assign}\frac{\Gamma \vdash c := a + b \qquad \text{addG}\ \dfrac{\Gamma \vdash a : \mathsf{Rat} \qquad \text{var}\ \dfrac{\Gamma \vdash b : \mathsf{Int} \qquad \Gamma \vdash \mathsf{Int} \subseteq \mathsf{Rat}}{\Gamma \vdash b : \mathsf{Rat}}}{\Gamma \vdash a + b : \mathsf{Rat}}}{\Gamma \vdash c : \mathsf{Rat}}$$

5.4 algorithm2e

Algorithm 1: typeChecking

Input: Abstract syntax tree

Result: Type checking result; In addition, type table $\text{type}_{\text{type\_G}}$ for global variables, $\text{type}_{\text{game}}$ for the main game and type_{fun} for each $fun \in F$

```
1 while something changed in last cycle do
2     foreach global statement s do parseStatement(s, type_type_G);
3     ;
4     foreach function fun do
5         foreach statement s in fun do parseStatement(s, type_fun);
6         ;
7     foreach statement s in game do parseStatement(s, type_game);
8     ;
```

5.5 Pseudocode

```
expression
  : NUMBER
  | VARIABLE
  | '+' expression
  | expression '+' expression
  | expression '*' expression
  | function_name '(' parameters ')'
  | '(' expression ')'
```

Figure 5. Grammar of arithmetic expressions.

5.6 Frame Around Information

Tip: We can use minipage to create a frame around some important information.

1. integer division (\div) – only usable between Int types
2. remainder (%) – only usable between Int types

Figure 6. Arithmetic operations in ProveIt revisited.

6 Conclusion

what did you do?

What are the results?

future work?

References

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[4] Mihir Bellare and Phillip Rogaway. Code-based game-playing proofs and the security of triple encryption. Cryptology ePrint Archive, Report 2004/331, 2004. `http://eprint.iacr.org/`.

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[7] Bruno Blanchet. Proverif: Cryptographic protocol verifier in the formal model. `http://www.proverif.ens.fr/`.

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Appendix

I. Glossary

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