Title of the thesis

TITLE OF THE THESIS

BY

FIRST LAST[1], B.Eng.

A THESIS

SUBMITTED TO THE DEPARTMENT OF COMPUTING AND SOFTWARE

AND THE SCHOOL OF GRADUATE STUDIES

OF MCMASTER UNIVERSITY

IN PARTIAL FULFILMENT OF THE REQUIREMENTS

FOR THE DEGREE OF

MASTER OF APPLIED SCIENCE

Master of Applied Science (20xx)	McMaster University
(Software Engineering)	Hamilton, Ontario, Canada

TITLE:	Title of the thesis
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SUPERVISOR:	Dr. First Last
NUMBER OF PAGES:	xi, 132

To my family

Abstract

Motivation paragraph.

What is the problem paragraph.

The meat of the thesis goes here (how we solve the problem).

Conclusion: why is our solution of interest.

Acknowledgements

Acknowledge 1st.

Acknowledge 2nd.

Any awards / bursaries that made this possible.

Acknowledge very special.

Contents

List of Tables

List of Figures

Chapter 1

Introduction

In this chapter, we introduce XYZ. In Section 1.1, we give an introduction to XYZ and explain its ever-growing importance in today's society. In Section 1.2, we introduce XYZ and indicate their use in computer systems. In Section 1.3, we provide a review of the literature and discuss some existing techniques for XYZ while indicating how the existing techniques are not sufficient to ABC. In Section 1.4, we give the motivation for a new technique to ABC. In Section 1.5, we state the problem subject of our work. In Section 1.6, we summarize our contributions. Finally, in Section 1.7, we give the structure of the remainder of the thesis.

1.1 General Context

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Lorem ipsum has three facets which have a strong relationship to ABC: confidentiality, integrity, and availability [Bis02]. Confidentiality refers to consectetur adipiscing elit. Sed posuere eros ac nisi feugiat commodo. Curabitur sit amet ex feugiat, efficitur felis ut, mollis massa. Aliquam odio quam, tincidunt ut efficitur nec, condimentum in odio. Duis sagittis in risus id laoreet. Etiam ut nisi odio. Integrity refers to consectetur adipiscing elit. Sed posuere eros ac nisi feugiat commodo. Curabitur sit amet ex feugiat, efficitur felis ut, mollis massa. Aliquam odio quam, tincidunt ut efficitur nec, condimentum in odio. Duis sagittis in risus id laoreet. Etiam ut nisi odio. Availability refers to the consectetur adipiscing elit. Sed posuere eros ac nisi feugiat commodo. Curabitur sit amet ex feugiat, efficitur felis ut, mollis massa. Aliquam odio quam, tincidunt ut efficitur nec, condimentum in odio. Duis sagittis in risus id laoreet. Etiam ut nisi odio. Confidentiality, integrity, and availability are strongly related to consectetur adipiscing elit. Sed posuere eros ac nisi feugiat commodo. Curabitur sit amet ex feugiat, efficitur felis ut, mollis massa. Aliquam odio quam, tincidunt ut efficitur nec, condimentum in odio. Duis sagittis in risus id laoreet. Etiam ut nisi odio.

1.2 Specific Context

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1.3 Literature Survey of XYZs

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1.4 Motivation

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1.5 Problem Statement

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1.6 Main Contributions

The main contributions to the XYZ include:

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(ii) Curabitur rutrum non lacus id tristique. Duis efficitur condimentum risus ac egestas.

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1.7 Structure of the Thesis

The remainder of this thesis is organized as follows:

Chapter 2 introduces the required mathematical background including MNO theory.

Chapter 3 provides a number of examples of ways in which XYZ.

Chapter 4 describes the process by which we formulate a new technique to ABC.

Chapter 5 gives a number of illustrative examples demonstrating the application of the proposed XYZ.

Chapter 6 discusses the impact of our approach in helping to remedy the problem of XYZ.

Chapter 7 draws conclusions and suggests future work.

Chapter 2

Mathematical Background

In this chapter, we introduce the necessary mathematical concepts required for the understanding of the material presented in the thesis. In Section 2.1, we give an introduction to ABC. In Section 2.2, we give definitions and examples of EFG. Finally, in Section 2.3, we conclude with a summary of the core concepts and describe where they are used throughout the remainder of the thesis.

2.1 Section One

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2.2 Section Two

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Definition 2.2.1. *Given two sets, A and B, we define the Cartesian product $A \times B$ as*

$$A \times B = \{(x, y) \mid x \in A \ \wedge \ y \in B\}$$

2.3 Conclusion

The objective of this chapter is to give readers the required mathematical background of our approach. We have presented ABC and EFG since we will be ... will be discussed further in Chapter 4.

Chapter 3

Survey

In this chapter, we aim to provide some insight lorem ipsum dolor sit amet, consectetur adipiscing elit. In Section 3.1, I give a short discussion of the one. In Sections 3.2 and **??**, I present a non-exhaustive summary of ABC. In Section 3.3 we discuss how XYZ.

3.1 One

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3.2 Two

In this section, I present a number of XYZ.

3.2.1 Two One

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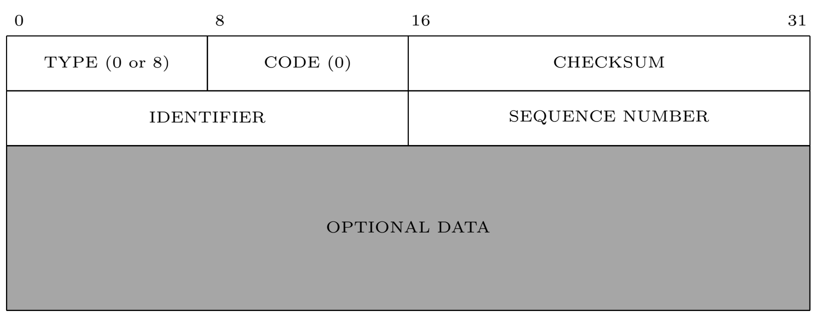

Figure 3.1: ICMP echo request or reply message format.

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3.3 Conclusion

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Chapter 4

Main Chapter

In this chapter, we formulate a new XYZ. In Section 4.1, we list our assumptions. In Section 4.2, we give a clear mathematical representation of the problem of XYZ. In Section 4.3, we present our technique.

4.1 Assumptions

In formulating the problem of XYZ, we make the following assumptions:

(i) Assumption one.

(ii) Assumption two.

(iii) Assumption three.

4.2 Mathematical Representation

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$$\begin{tikzcd} & & \mathbb{D}_Q \\ \mathbb{N} \arrow[urr, "Q"] \arrow[rr, "P"'] & & \mathbb{D}_P \arrow[u, "X"'] \end{tikzcd}$$

Figure 4.1: Diagram representing the relationship between the relation P and Q via the abstraction relation X.

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4.3 The Proposed Technique

The proposed technique for the detection of the leak of confidential information via covert channels has two components: monitoring the information sent on the communication channels and finding an abstraction relation relating the confidential information to the information observed to be sent on the communication channel(s).

4.3.1 Monitoring the Communication Channels

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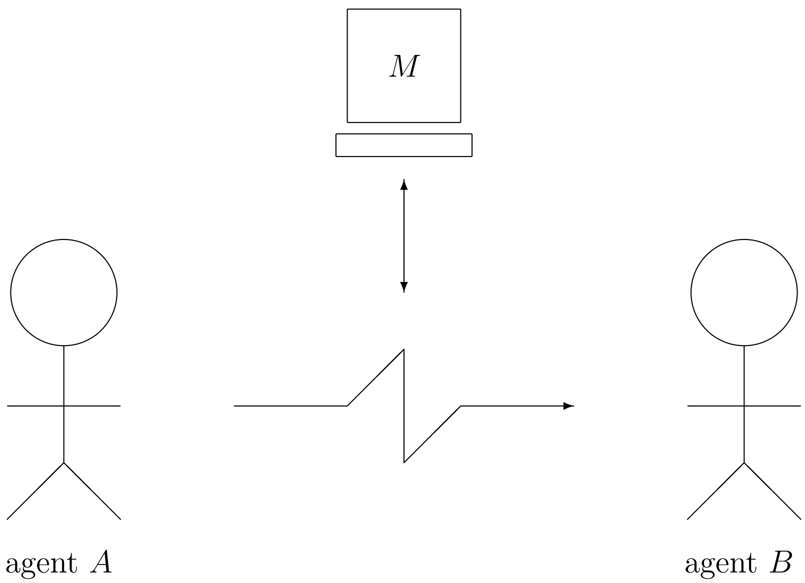

Figure 4.2: A scenario consisting of two agents communicating while being monitored.

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4.4 Conclusion

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Chapter 5

Application of Main

In this chapter, we look at how the XYZ technique formulated in Chapter 4 can be applied to different scenarios involving ABC. Through a series of examples, we will see the versatility of the MNP technique and how it can be used to ABC.

In this chapter, we automate the given examples using the XYZ tool. For more information regarding the use of the XYZ tool, refer to Appendix A.

5.1 Application One

We continue with the illustrative example introduced in Section 4.3. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Cras et nibh vel mauris pharetra viverra. Integer nisl nibh, ullamcorper eget imperdiet sed, accumsan ultrices purus. Quisque malesuada vel elit in cursus. Vestibulum rutrum turpis sed lectus vehicula, et venenatis ligula varius. Vivamus auctor fermentum libero, in ullamcorper diam pulvinar non. Donec condimentum cursus iaculis. Nulla odio dolor, faucibus eget mauris a, eleifend congue erat. Interdum et malesuada fames ac ante ipsum primis in faucibus. Nullam aliquet finibus ligula eu feugiat. Aenean feugiat nunc et arcu elementum vestibulum.

Through Example 5.1.1 we will show that nulla vulputate ultricies felis, ut feugiat nisl auctor a. Lorem ipsum dolor sit amet, consectetur adipiscing elit.

Example 5.1.1. *Consider a case where the set of confidential information is represented as* $P = \{(1,3),(2,1),(3,4),(4,1),(5,5),(6,9)\}$. *Suppose that agent A sends this information encrypted over a single communication channel as* $Q = \{(1,12),(2,1),(3,16),(4,1),(5,17),(6,18)\}$.

We define the relations P and Q in ***RELVIEW*** *as follows:*

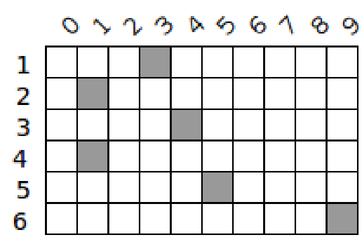

Figure 5.1: Relation P for Example 5.1.1.

We verify the existence of an abstraction relation by applying Corollary **??** *using* ***RELVIEW****. By executing Program A.2.1 (Result* $= Test(P,Q)$*), we obtain the following result:*

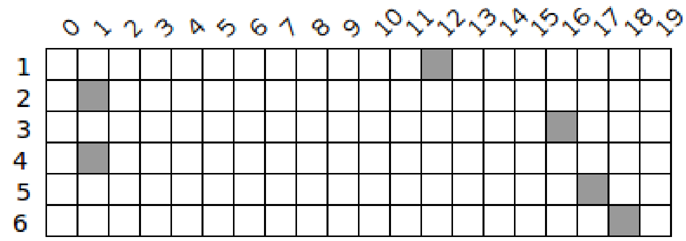

Figure 5.2: Relation Q for Example 5.1.1.

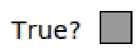

Figure 5.3: Relation *Result* for Example 5.1.1.

Therefore, the test has passed meaning that there exists an abstraction relation relating the confidential information to the information observed to be sent on the communication channel. This means that we can apply Corollary **??** *by executing Program A.2.2* ($X = Compute(P, Q, \mathbb{L})$) *to obtain the abstraction relation,* X*.*

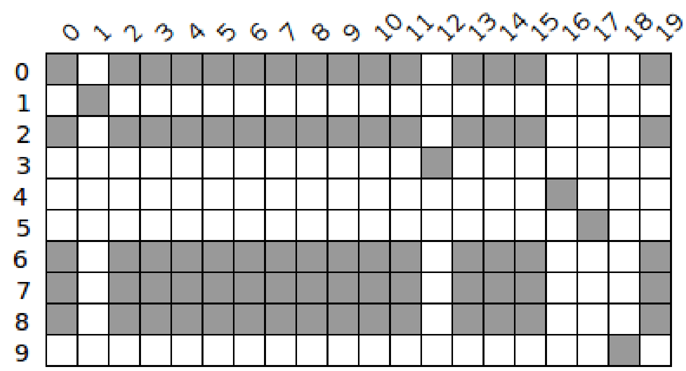

Figure 5.4: Abstraction relation X for Example 5.1.1.

From this result, we can see that there are some digits which are related to information which we do not necessarily have an interest in, i.e., we are only concerned with the confidential information which consists of the digits $1, 3, 4, 5,$ *and* 9*. Therefore* *we can design a filter R which can be used to refine the abstraction relation X. We define R in* ***RELVIEW*** *as follows:*

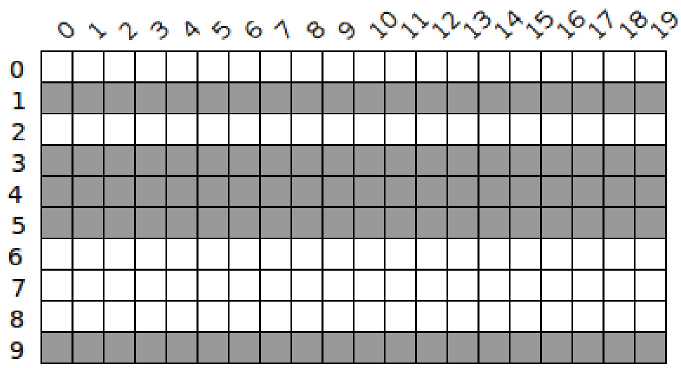

Figure 5.5: Filtering relation R for Example 5.1.1.

By executing Program A.2.2 with the filter R, ($X_{filtered} = Compute(P, Q, R)$), we obtain the abstraction relation, $X_{filtered}$

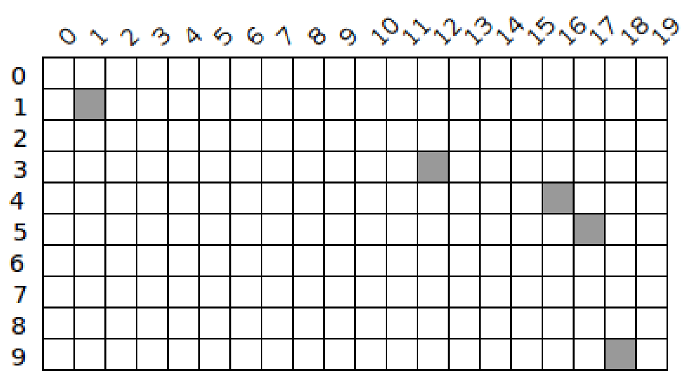

Figure 5.6: Abstraction relation $X_{filtered}$ for Example 5.1.1.

5.2 App Two

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This idea is best illustrated through Example 5.2.1.

Example 5.2.1. *Assume the set of confidential information is given as* $P = \{(1,3),(2,1),(3,4),(4,1),(5,5),(6,9)\}$. *In order to obscure the transmission of the information, agent A modulates the confidential information by a relation represented by*

$M = \{(0,9),(1,0),(2,1),(3,2),(4,3),(5,4),(6,5),(7,6),(8,7),(9,8)\}$ *prior to its encryption. Then, the new relation representing the confidential information is given by* $(P\,;M) = \{(1,2),(2,0),(3,3),(4,0),(5,4),(6,8)\}$. *This information is encrypted and sent on a single communication channel as* $Q = \{(1,11),(2,0),(3,12),(4,0),(5,16),(6,8)\}$.

*We define the relations P, M and Q in **`RELVIEW`** as follows:*

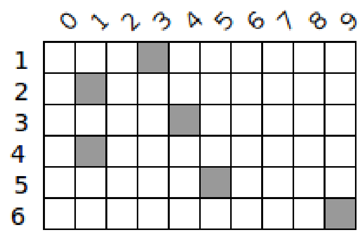

Figure 5.7: Relation P for Example 5.2.1.

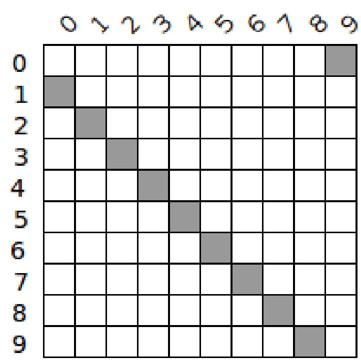

Figure 5.8: Modulation relation M for Example 5.2.1.

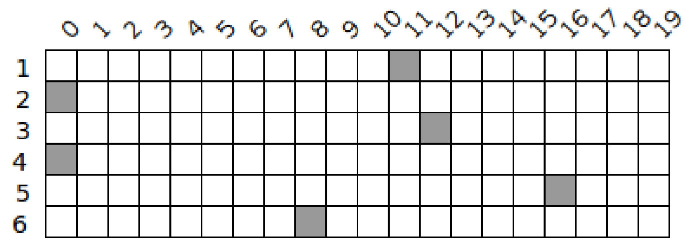

Figure 5.9: Relation Q for Example 5.2.1.

The modulated confidential information is represented in ***RELVIEW*** *as follows:*

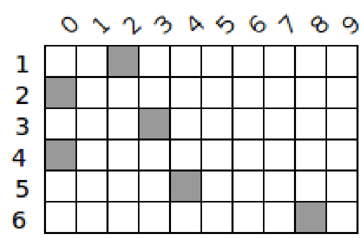

Figure 5.10: Relation $(P\,;M)$ for Example 5.2.1.

We verify the existence of an abstraction relation by executing Program A.2.1 (Result = $Test(P, Q)$*). In this case we are looking for an abstraction relation relating the confidential information, P, and the information sent on the communication channel, Q, which corresponds to the encrypted modulated confidential information.*

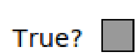

Figure 5.11: Relation *Result* for Example 5.2.1.

Therefore, the test has passed so we can compute the abstraction relation by executing Program A.2.2 ($X = Compute(P, Q, R)$) where R is the filtering relation.

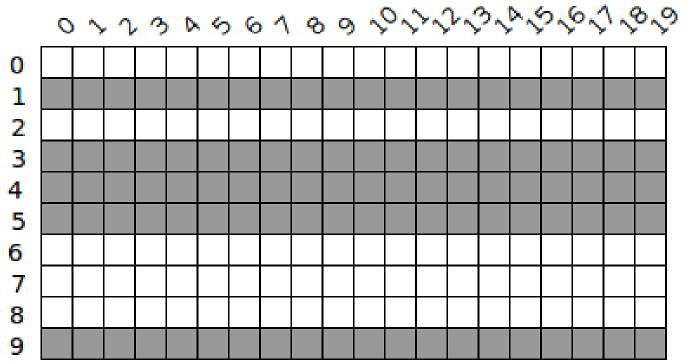

Figure 5.12: Filtering relation R for Example 5.2.1.

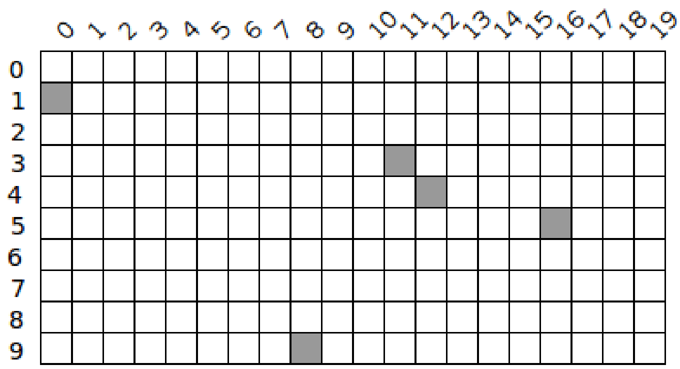

Figure 5.13: Abstraction relation X for Example 5.2.1.

5.3 Conclusion

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Chapter 6

Discussion

In this chapter, we discuss various aspects of the problem ofXYZ. In Section 6.1, we discuss some possible application domains for which the XYZn technique presented in Chapter 4 is suitable. We also discuss the importance of such techniques and applications. In Section 6.2, we assess the strengths and weaknesses of the main contributions.

6.1 Discussion

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6.2 Assessment of the Contributions

In this section, we discuss the strengths and weaknesses of the main contributions presented in this thesis. It is important to highlight both the strengths and weaknesses of the models and techniques that are developed so that we are able to further refine a solution to the problem of XYZ and possibly one day eliminate their use completely.

6.2.1 Strengths of the Contributions

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6.2.2 Weaknesses of the Contributions

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mollis neque. Nunc luctus, sapien et auctor faucibus, justo metus ultricies nulla, nec consequat augue magna quis quam. Curabitur tristique bibendum vehicula. Sed quis dictum odio. Donec eget vestibulum sem. Nullam facilisis libero vel justo mattis luctus. Suspendisse auctor fringilla mi non varius. Proin vitae quam massa. Nam sit amet tristique urna, quis pharetra diam. Cras efficitur enim sed accumsan imperdiet. Vivamus euismod non odio nec semper.

6.3 Conclusion

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Chapter 7

Conclusion and Future Work

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7.1 Future Work

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7.1.1 Theory: Models and Techniques

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7.1.2 Applications

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7.1.3 Tools/Automation

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7.2 Closing Remarks

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Appendix A

RELVIEW

To aid in the computation of the examples presented in this thesis, we use a tool called RELVIEW. RELVIEW is an interactive tool for computer-aided manipulation of relations represented as Boolean matrices. It is developed at the Department of Computer Science and Applied Mathematics at Christian-Albrechts-University in Kiel, Germany [Ber09]. This appendix presents an overview of working with RELVIEW and the programs developed in RELVIEW to automate the tests and computations of the corollaries presented in Chapter ??.

A.1 Working With RELVIEW

In this section, we look at how to work with relations using the RELVIEW tool. The information presented in this section is taken from [BBS09].

A.1.1 Representing Relations

`RELVIEW` is able to represent relations both as Boolean matrices and as an ASCII description.

Boolean Matrix Representation

The Boolean matrix representation of relations in `RELVIEW` is a graphical representation. A relation is given as a matrix where the rows represent the domain of the relation and the columns represent the range of the relation. A filled in cell of the matrix represents that element being included in the relation. An example of Boolean matrix representation of a relation in `RELVIEW` is given in Figure A.1.

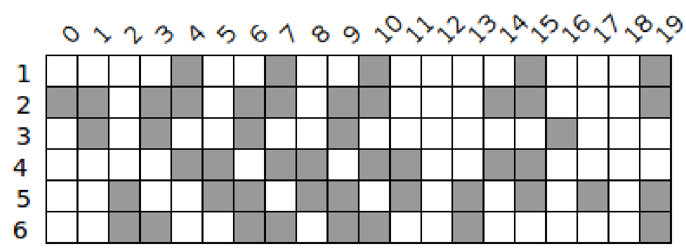


Figure A.1: Example of the Boolean matrix representation of a relation in `RELVIEW`.

ASCII Representation

The ASCII representation of relations in `RELVIEW` is a textual representation. A relation is given as a list entries of the form "`Domain : Range`". The ASCII representation of the relation given in Figure A.1 is given below.

```
R (6, 20)
1 : 5, 8, 11, 16, 20
2 : 1, 2, 4, 5, 7, 8, 10, 11, 15, 16, 20
3 : 2, 4, 7, 10, 17
4 : 5, 6, 8, 9, 11, 12, 15, 16
5 : 3, 6, 7, 9, 10, 12, 14, 16, 18, 20
6 : 3, 4, 7, 8, 10, 11, 14, 20
```

A.1.2 Operations

Syntax	Description
$-R$	Complement of relation R
$R \mid S$	Union (join) of R and S
$R \,\&\, S$	Intersection (meet) of R and S
$R + S$	Relational sum of R and S

Table A.1: Boolean Operations

Syntax	Description
$R\hat{}$	Converse of relation R
$R * S$	Composition of R and S

Table A.2: Relational Algebraic Operations

Syntax	Description
S/R	Left residue of R and S
$R\backslash S$	Right residue of R and S
$syq(R, S)$	Symmetric quotient of R and S

Table A.3: Residuals and Symmetric Quotients

Syntax	Description
$eq(R, S)$	Test, whether R and S are equal
$incl(R, S)$	Test, whether R is included in S

Table A.4: Relational Tests

A.1.3 Labels

Labels are organized into sets which are mappings from natural numbers to labels or identifiers.

The labels that are used in this thesis are given below:

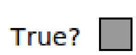
```
Digit = { 1 "0", 2 "1", 3 "2", 4 "3", 5 "4", 6 "5", 7 "6", 8 "7", 9
    "8", 10 "9" }

Encryption = { 1 "0", 2 "1", 3 "2", 4 "3", 5 "4", 6 "5", 7 "6", 8
    "7", 9 "8", 10 "9", 11 "10", 12 "11", 13 "12", 14 "13", 15 "14",
     16 "15", 17 "16", 18 "17", 19 "18", 20 "19" }

Bool = { 1 "True?" }
```

These labels are used in the Boolean matrix representation of relations making them easier to read and understand. The label “Digit” corresponds to the digit data type, the label “Encryption” corresponds to the natural numbers which can be used to encrypt the digits, and the label "Bool" simply adds a descriptive label for boolean results.

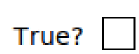
It is important to note that when representing relations using labels, the ASCII representation of the relation must correspond to the natural number and not the label or identifier. For example, if we want to represent the digit 4 being sent at time 1, i.e., $(1, 4)$ we must use "1 : 5" in the ASCII representation so that the label corresponds to the digit 4.

A.1.4 Truth Values

In `RELVIEW`, the result of a Boolean operation is a 1×1 Boolean matrix with the truth values corresponding to $\mathbb{L} = \mathsf{true}$ and $\emptyset = \mathsf{false}$. This is to say that the truth values are given by the Boolean matrices given in Figure A.2.



(a) True



(b) False

Figure A.2: `RELVIEW` representation of truth values.

A.2 `RELVIEW` Programs

Program A.2.1 represents the test outlined in Corollary ??.

Program A.2.1.

```
Test(p,q)
    DECL test1, test2, res
    BEG  test1 = eq(p,q*(q\p));
         test2 = eq(q,p*(p\q));
         res = test1 | test2
         RETURN res
    END.
```

Program A.2.2 corresponds to the computations presented in Corollary **??**.

Program A.2.2.

```
Compute(p, q, r)
    DECL test1, test2, res
    BEG  test1 = incl(p,q*(r^ & (q\p)));
         test2 = incl(q,p*(r  & (p\q)));
         IF test1 & test2
            THEN res = r & syq(p,q)
            ELSE IF test1
                THEN res = r & (q\p)^
                ELSE IF test2
                    THEN res = r & (p\q)
                    ELSE res = false
                FI
            FI
         FI
         RETURN res
    END.
```

Program A.2.3 automates the computation given in Corollary **??**.

Program A.2.3.

```
ComputeBij(p, q, r)
    DECL test1, test2, res
    BEG IF eq((p\q),(q\p)^)
            THEN res = r & (p\q)
            ELSE res = false
        FI
        RETURN res
    END.
```

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