



NTNU – Trondheim
Norwegian University of
Science and Technology

Cyber Insurance

Håvard Halse
Jonas Hoemsnes

Submission date: January 2013
Responsible professor: Jan A. Audestad, Affiliation
Supervisor: Gergely Biczók, Affiliation

Norwegian University of Science and Technology
Department of Telematics

Abstract

Hello, here is some text without a meaning. This text should show what a printed text will look like at this place. If you read this text, you will get no information. Really? Is there no information? Is there a difference between this text and some nonsense like “Huardest gefburn”? Kjift – not at all! A blind text like this gives you information about the selected font, how the letters are written and an impression of the look. This text should contain all letters of the alphabet and it should be written in of the original language. There is no need for special content, but the length of words should match the language.

This is the second paragraph. Hello, here is some text without a meaning. This text should show what a printed text will look like at this place. If you read this text, you will get no information. Really? Is there no information? Is there a difference between this text and some nonsense like “Huardest gefburn”? Kjift – not at all! A blind text like this gives you information about the selected font, how the letters are written and an impression of the look. This text should contain all letters of the alphabet and it should be written in of the original language. There is no need for special content, but the length of words should match the language.

And after the second paragraph follows the third paragraph. Hello, here is some text without a meaning. This text should show what a printed text will look like at this place. If you read this text, you will get no information. Really? Is there no information? Is there a difference between this text and some nonsense like “Huardest gefburn”? Kjift – not at all! A blind text like this gives you information about the selected font, how the letters are written and an impression of the look. This text should contain all letters of the alphabet and it should be written in of the original language. There is no need for special content, but the length of words should match the language.

After this fourth paragraph, we start a new paragraph sequence. Hello, here is some text without a meaning. This text should show what a printed text will look like at this place. If you read this text, you will get no information. Really? Is there no information? Is there a difference between this text and some nonsense like “Huardest gefburn”? Kjift – not at all! A blind text like this gives you information about the selected font, how the letters are written and an impression of the look. This text should contain all letters of the alphabet and it should be written in of

the original language. There is no need for special content, but the length of words should match the language.

Hello, here is some text without a meaning. This text should show what a printed text will look like at this place. If you read this text, you will get no information. Really? Is there no information? Is there a difference between this text and some nonsense like “Huardest gefburn”? Kjift – not at all! A blind text like this gives you information about the selected font, how the letters are written and an impression of the look. This text should contain all letters of the alphabet and it should be written in of the original language. There is no need for special content, but the length of words should match the language.

Preface

Hello, here is some text without a meaning. This text should show what a printed text will look like at this place. If you read this text, you will get no information. Really? Is there no information? Is there a difference between this text and some nonsense like “Huardest gefburn”? Kjift – not at all! A blind text like this gives you information about the selected font, how the letters are written and an impression of the look. This text should contain all letters of the alphabet and it should be written in of the original language. There is no need for special content, but the length of words should match the language.

Contents

List of Figures	ix
List of Tables	xi
List of Algorithms	xiii
1 Chapter 1	1
1.1 First section	2
1.1.1 First subsection with some <i>Math</i> symbol	2
1.1.2 Mathematics	2
1.1.3 Source code example	3
2 Relatedwork	5
2.1 Towards Insurable Network Architectures	5
2.2 Cyber insurance as an Incentive for Internet Security	6
2.2.1 Classical model for insurance	7
2.2.2 Interdependent security and insurance	7
2.3 Modeling cyber-insurance: towards a unifying Framework	8
2.3.1 Demand side agents	9
2.3.2 Supply side, insurers	9
2.3.3 Information structure	9
2.3.4 A novel cyber-insurance Model	10
2.3.5 A solution to the information Asymmetry Problem	10
2.3.6 Cyber-insurance for cyber-security, A topological Take on Mod- ulating Insurance Premiums	11
3 Related work 2	13
3.1 First section	15
3.1.1 First subsection with some <i>Math</i> symbol	15
3.1.2 Mathematics	15
3.1.3 Source code example	16

List of Figures

1.1	A figure	2
2.1	A figure	5
3.1	A figure	14

List of Tables

1.1	A table	3
3.1	A table	15

List of Algorithms

1.1	The Hello World! program in Java.	3
3.1	The Hello World! program in Java.	16

Chapter 1

TEST TEST TEST TEST Here is an example of how to use acronyms such as Norwegian University of Science and Technology (NTNU). The second time only NTNU is shown and if there were several you would write NTNUs. And here is an example¹ of citation [?].

This is the second paragraph. Hello, here is some text without a meaning. This text should show what a printed text will look like at this place. If you read this text, you will get no information. Really? Is there no information? Is there a difference between this text and some nonsense like “Huardest gefburn”? Kjift – not at all! A blind text like this gives you information about the selected font, how the letters are written and an impression of the look. This text should contain all letters of the alphabet and it should be written in of the original language. There is no need for special content, but the length of words should match the language.

And after the second paragraph follows the third paragraph. Hello, here is some text without a meaning. This text should show what a printed text will look like at this place. If you read this text, you will get no information. Really? Is there no information? Is there a difference between this text and some nonsense like “Huardest gefburn”? Kjift – not at all! A blind text like this gives you information about the selected font, how the letters are written and an impression of the look. This text should contain all letters of the alphabet and it should be written in of the original language. There is no need for special content, but the length of words should match the language.

After this fourth paragraph, we start a new paragraph sequence. Hello, here is some text without a meaning. This text should show what a printed text will look like at this place. If you read this text, you will get no information. Really? Is there no information? Is there a difference between this text and some nonsense like “Huardest gefburn”? Kjift – not at all! A blind text like this gives you information

¹A footnote



Figure 1.1: A figure

about the selected font, how the letters are written and an impression of the look. This text should contain all letters of the alphabet and it should be written in of the original language. There is no need for special content, but the length of words should match the language.

1.1 First section

1.1.1 First subsection with some *Math* symbol

Hello, here is some text without a meaning. This text should show what a printed text will look like at this place. If you read this text, you will get no information. Really? Is there no information? Is there a difference between this text and some nonsense like “Huardest gefburn”? Kjift – not at all! A blind text like this gives you information about the selected font, how the letters are written and an impression of the look. This text should contain all letters of the alphabet and it should be written in of the original language. There is no need for special content, but the length of words should match the language.

- item1
- item2
- ...

1.1.2 Mathematics

Hello, here is some text without a meaning. This text should show what a printed text will look like at this place. $\sin^2(\alpha) + \cos^2(\beta) = 1$. If you read this text, you

Table 1.1: A table

a	b	c	d	e
f	g	h	i	j
k	l	m	n	o
p	q	r	s	t
u	v	w	x	y
z	æ	ø	å	

will get no information $E = mc^2$. Really? Is there no information? Is there a difference between this text and some nonsense like “Huardest gefburn”? Kjift – not at all! A blind text like this gives you information about the selected font, how the letters are written and an impression of the look. $\sqrt[n]{a} \cdot \sqrt[n]{b} = \sqrt[n]{ab}$. This text should contain all letters of the alphabet and it should be written in of the original language. $\frac{\sqrt[n]{a}}{\sqrt[n]{b}} = \sqrt[n]{\frac{a}{b}}$. There is no need for special content, but the length of words should match the language. $a \sqrt[n]{b} = \sqrt[n]{a^n b}$.

Proposition 1.1. *A proposition... (similar environments include: theorem, corollary, conjecture, lemma)*

Proof. And its proof. □

1.1.3 Source code example

Algorithm 1.1 The Hello World! program in Java.

```
class HelloWorldApp {
    public static void main(String[] args) {
        //Display the string
        System.out.println("Hello World!");
    }
}
```

You can refer to figures using the predefined command like Figure 3.1, to pages like page 14, to tables like Table 3.1, to chapters like Chapter ?? and to sections like Section 3.1 and you may define similar commands to refer to proposition, algorithms etc.

Chapter 2

Relatedwork

2.1 Towards Insurable Network Architectures

A trusted component or system is one you can insure. Cyber insurance gives an incentive to better secure your network, and will thus reduce the overall threat for both first and third parties. It will also promote gathering and sharing of information related to security incidents. All in all this will increase the social welfare by decreasing the variance of losses. But even if cyber insurance seems very profitable for everyone, it has failed to evolve as much as expected. Some reasons for this, could be:

- lack of data to calculate premium.
- Underdeveloped demand due to missing awareness for cyber risks.
- legal and procedural hurdles in substantiating claim.

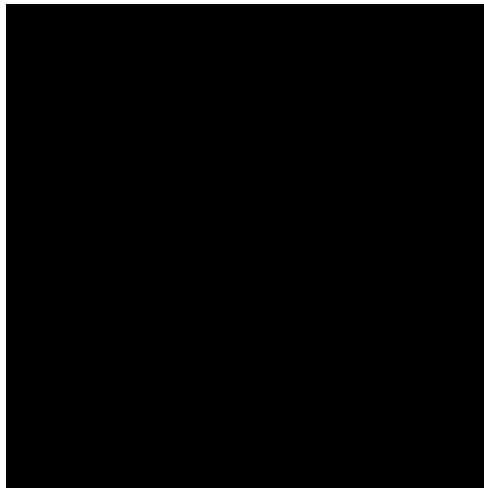


Figure 2.1: A figure

A more economic model to describe why cyber insurance is still such a niche market.

Interdependent security Expected loss due to security breach at one agent is not only dependent on this agents lvl of security, but also by other agents security investment. A good example is spam, it is dependent of number of compromised computers. This also generates an externality and encourages to free riding. which then leads to underinvestment in security.

Correlated risks Many systems share common vulnerabilities, which can be exploited at the same time. This leads to a more likely occurrence of extreme and catastrophic events, which will result in uneconomical supply of cyber insurance.

information asymmetry Since measuring security strength is very hard, people have a high incentive for hiding info. This leads to information asymmetry. All these three form a triple obstacle, which eliminates the market in evolving. All these obstacles evolve from what makes ICT succeed, distribution, interconnection, universality and reuse. This is why Architecture matters. The obstacles does not arrive from properties of individual agents, but from integration and interaction in networking. Networking is not just physical, but a abstract structure mapping physical, logical and social interconnection. A good example is development tool chains. A web-browser is not just dependent of the security the developers have implemented, but also the security in the tools used, such as libraries. These three problems have never been analysed together, this is what this paper contributes with. Uses GT to model incentives of the different agents.

2.2 Cyber insurance as an Incentive for Internet Security

so far the risk management on the internet has involved methods to reduce the risks(firewalls, ids, prevention etc.) but not eliminate risk. Is it logical to buy insurance to protect the internet and its users. An important thing to notice when insuring internet, is that the entities on the internet are correlated, which means insurance claims will likely be correlated. Risks are interdependent, decision by an entity to invest in security affects the risks of others. Key result: using insurance would increase the overall security. Act as an powerful incentive, which pushes entities over the threshold where they invest in self-protection. Insurance should be an important component of risk management in the internet.

Four typical options available in the face of risks. 1. avoid the risk 2. retain 3. self protect and mitigate 4. transfer the risk. Most entities in the internet have choses a mix of 2 and 3. This has lead to lots of systems trying to detect threats and anomalies(both malicious and accidental) and to protect the users and the structure from these. but this does not eliminate risk, threats evolve over time and there is

always accidents. How to handle this residual risk? Option 4, transfer the risk to another entity who willingly accept it(hedging), insure in exchange for a fee. Allows for predictable payouts for uncertain events. But does this makes sense for the internet, benefits, to whom? and to what extent?

How to model insurance and computing premiums. avoid ruin the insurer. Actuarial approach. Economic approach: premium should be negative correlated to the amount invested in security by the entity. Users can chose to invest c or not in security solutions. Shown that in the 2 user case in absence of insurance, there is a NE in a good state, if c is low enough. These result have been extended to a network setting. This paper starts out by adding insurance to the two person game, then the n -users network, where damages spread among the users. They show that if premium discriminates about investment in protection. Insurance is a strong incentive to invest in security. Also show how insurance can be a mechanism to facilitate the deployment of security investments by taking advantage network effects such as treshold or tipping point dynamics. Uses simple models.

Using cyber insurance as a way to handle residual risk started out early in the 90's. Software and insurance sold as packages. More recently insurance companies started offering standalone products. A challenging problem is the correlation between risks, interdependent risks(risk that depend on the behavior of others).

2.2.1 Classical model for insurance

agents try to maximize some kind of expected utility function, and are risk averse. $u[w_0 - \pi] = E[u[w_0 + X]]$ Investments for an agent is either self protect and or insurance. If insurance premium is not negatively correlated to the self protection, we get moral hazard. Because if not, insurance will discourage self protection. In this way insurance can co-exist with selfprotection.

2.2.2 Interdependent security and insurance

In presence of interdependent risks, the reward for a user investing in self-protection depends on the security in the rest of the network. Discrete choice, invest or not. loss occurs directly or indirectly. Cost of investing is c . This avoids the direct loss completely. In summary, insurance provides incentives for a small fraction of the population to invest in self-protection, which in turn induces the rest of the population to invest in self-protection as well, leading to the desirable state where all users in the network are self-protected. Furthermore, the parameter y provides a way to multiply the benets of insurance, by lowering the initial fraction of the self-protected population needed to reach the desirable state. This paper shows that insurance provides significant benefits to network of users facing correlated, interdependent risks. Insurance is a powerful mechanism to promote network-wide changes, i.e lead

to self protection. How to estimate damage? This is very hard on the internet. This paper shows how it is economical rational for entities to prefer a relatively insecure system to a more secure, and that the adoption of security investments follows threshold/tipping point dynamics. And that insurance is a powerful incentive to push the users over the threshold.

2.3 Modeling cyber-insurance: towards a unifying Framework

Cyberinsurance, the transfer of financial risk associated with network and computers incidents to a third party, has been researched for several years. But reality continues to disappoint. Sets back by physical accidents such as 9/11 Y2K etc. Clients are for the most SMBs. All three obstacles has to be overcome at the same time to fix the market, to do this we need a comprehensiv framework for modelling cyber-risk and cyber-insurance. many researchers have lost their optimism about cyberinsurance, but this paper has not. Breaks the modeling down to five key components:

- network environment(nodes controlled by agents, who extract utility. The risk comes from here
- demand side(agents)
- supply side(insurers)
- information structure, distribution of knowledge among the players.
- organizational environment. public and private entities whose actions affect network security and agents security decisions.

what can be answered with models of cyber insurance markets?

Looking at equilibrium we can determine under which conditions will a market for cyber-insurance thrive? or what are the reasons for failure.

What is the effect of an insurance market on aggregate network security? Will the internet become more secure?

What are the contributions to social welfare?

function Defense function D describes how security investment affects the probability of loss p and the size of the loss l for individual nodes. In most general its a probability distribution. An agent i only chooses s_i .

network topology G Describes the relation between elements of an ordered set of nodes.(connectivity)

- star-shaped
- tree shaped
- ER

- Structured clusters

Risk arrival defined by the relation between network topology G and the value of the defense function D Cyber risk is characterized by both interdependent security and correlated risk.

Attacker model existing literature assume attacks are performed by "nature" rather than strategic players. But attackers react to agents and insurers decisions. this paper models attackers as players.

2.3.1 Demand side agents

Make security decisions for one or more nodes. When buying full coverage of risks, permits the agent to exchange uncertain future costs with a predictable premium. Agents have node control, they are either heterogen og homogeneous. They only seek insurance if they are risk averse. Full or partial insurance. A contract is called fair if the expected profit from it is zero(insurers point of view).

Selfprotection creates an externality, ie interdependent security. Selfinsurance does not generate externality, it only reduces your size of potential loss.

time, all choices are set only once, but not necessarily at the same time by all the agents.

2.3.2 Supply side, insurers

It is important to include these as players. Five attributes: market structure, risk aversion, markup, contract design and higherorder risk transfer. Marketstructure, monopoly, oligopoly or competition. Homegenous or heterogenous? Competitions leads to low MC. Risk aversion to avoid taking excessive risk and bankruptcy, need a safety capital. Markup: insurers profit, admin-costs, cost of safety capital. Contract design: fixed premium, premium differentiation, contract with fines. Higher order risk transfer: Cyber-reinsurance, catastrophe bonds, exploit derivatives.

2.3.3 Information structure

Symmetric and asymmetric. Leads to adverse selection if the insurer cant distinguish between the agents. Moral hazzard occurs if agents could undertake actions that affect the probability of loss ex post. Also information about security is hard to gather and evaluate,. . . All this results in two types of contract scenario, pooling or separation(agents sort them self out).

2.3.4 A novel cyber-insurance Model

eliminate threats which cannot be tackled through traditional means, such as AV. Risks arise due to both security attacks and non-security related failures. This paper analyzes cyber-insurance solutions when a user faces risks due to both of these. Propose a model called "Aegis", user accepts a fraction of loss recovery and transfers the rest. Mathematically show that only under conditions when buying cyber-insurance is mandatory.

2.3.5 A solution to the information Asymmetry Problem

AV and other security software reduces the risk, but does not remove it completely. Cyber-insurance, residual risk elimination. But a problem with this is information asymmetry. This paper proposes three mechanisms to resolve this problem. Mechanisms based on the principal agent problem, difficulties in motivating one party (the agent) to act in the best interests of another (the principal) rather than in his or her own interests. Arises in almost every case where a party pays another party to do something. The agent has more information than the principal, asymmetric.

- 1 cyber insurance who only provide partial coverage to the insureds will ensure greater self defense efforts.
- 2 the lvl of deductible per network user contract increases in a concave manner with the topological degree of the user.
- 3 Cyber-insurance market can be made to exist in the presence of monopolistic insurers.

Security experts claim that it is impossible to achieve perfect internet security just via technological advancements.

- 1 there do not always exist fool-proof ways to detect and identify. Even the best software available have false-positive, false-negative. And threats evolve automatically in response to AV-software being deployed.
- 2 The internet is a distributed system, different security interests and incentives per user. Might spend money to protect their own hard drive, but not on prevent its computer being used by an attacker for a DOS attack on a wealthy corporation.
- 3 Correlated and interdependent risks. As a result, a user who invest in security generates positive externality for others. Which will result in a free rider problem.

- 4 Network externalities due to lock-in and first mover effects of security software vendors affect the adoption of more advanced technology.
- 5 Security software suffer from lemons market.

Cyber-insurance and asymmetry insurers are unable to distinguish high and low risk users, i.e adverse selection. users undertaking actions, i.e moral hazard.

Difficult for insurers to gather information about applications, software installed, security habits etc. and users can hide information.

Users in general invest too little in self-defense relative to the socially efficient level due to the free-rider problem (externalities). Thus the challenge to improving overall network security lies in incentivizing end users to invest in sufficient amount of self defense.

2.3.6 Cyber-insurance for cyber-security, A topological Take on Modulating Insurance Premiums

Adopts a topological perspective in proposing a mechanism that accounts for the positive externalities, network location of users, and provide appropriate way to proportionally allocate fines/rebates on user premiums. Uses GT to prove. Consider a monopolistic cyber-insurer, providing full coverage. Each client is risk averse. A user's investment and location in network determines his risk type. Each user has a utility function dependent on the rest of the users. Node centrality, maps to the externality effects a node has on other network nodes. Uses eigenvectors and Bonacich papers. Both these assign relative importance scores to all nodes, based on the concept of connections.

Chapter 3

Related work 2

Virus and worm propagation on the Internet can be modeled as epidemic spreads. When we look a 2-agent model we can observe correlation between one agents choice of investing in protection. If agent 1 has a connection to agent 2, the probability of agent 2 being contagion is strongly correlated to the choice of agent 1. In the case where agent 1 invests in protection, agent 2 will not be infected. However, if chooses not to invest in protection, the probability of infection for agent 2 is p . After a number of equations the authors conclude that in presence of insurance, the optimal strategy for all users is to invest in self-protecting services as long as this cost is low enough.

Further the authors looks at the situation where the cost of selv-protection is different for different agents (heterogeneous users) in a complete graph (n-n). The conclusion states that insurance increase the adoption for a fraction of the users, which creates the cascading effect that the rest of the users also gains benefit from investing in insurance. We end up in a state where everyone in the network are self-protected.

Related work 2. TEST TEST TEST Here is an example of how to use acronyms such as NTNU. The second time only NTNU is shown and if there were several you would write NTNUs. And here is an example¹ of citation [?].

Hello, here is some text without a meaning. $d\Omega = \sin\vartheta d\vartheta d\varphi$. This text should show what a printed text will look like at this place. If you read this text, you will get no information. Really? Is there no information? Is there a difference between this text and some nonsense like “Huardest gefburn”? Kjift – not at all! A blind text like this gives you information about the selected font, how the letters are written and an impression of the look. $\sin^2(\alpha) + \cos^2(\beta) = 1$. This text should contain all letters of the alphabet and it should be written in of the original language $E = mc^2$. There

¹A footnote

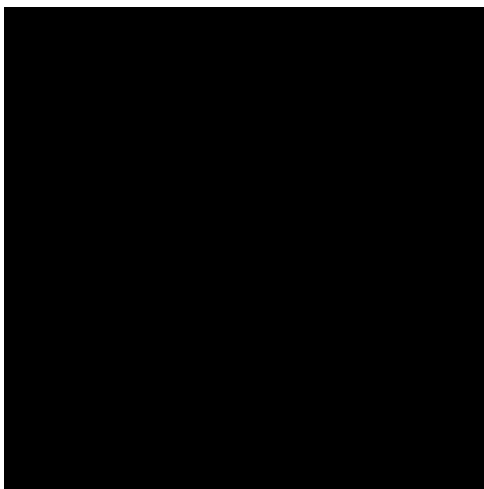


Figure 3.1: A figure

is no need for special content, but the length of words should match the language.
 $\sqrt[n]{a} \cdot \sqrt[n]{b} = \sqrt[n]{ab}$.

This is the second paragraph. Hello, here is some text without a meaning. This text should show what a printed text will look like at this place. $\sin^2(\alpha) + \cos^2(\beta) = 1$. If you read this text, you will get no information $E = mc^2$. Really? Is there no information? Is there a difference between this text and some nonsense like “Huardest gefburn”? Kjift – not at all! A blind text like this gives you information about the selected font, how the letters are written and an impression of the look. $\sqrt[n]{a} \cdot \sqrt[n]{b} = \sqrt[n]{ab}$. This text should contain all letters of the alphabet and it should be written in of the original language. $\frac{\sqrt[n]{a}}{\sqrt[n]{b}} = \sqrt[n]{\frac{a}{b}}$. There is no need for special content, but the length of words should match the language. $a \sqrt[n]{b} = \sqrt[n]{a^n b}$.

And after the second paragraph follows the third paragraph. Hello, here is some text without a meaning. This text should show what a printed text will look like at this place. $\sin^2(\alpha) + \cos^2(\beta) = 1$. If you read this text, you will get no information $E = mc^2$. Really? Is there no information? Is there a difference between this text and some nonsense like “Huardest gefburn”? Kjift – not at all! A blind text like this gives you information about the selected font, how the letters are written and an impression of the look. $\sqrt[n]{a} \cdot \sqrt[n]{b} = \sqrt[n]{ab}$. This text should contain all letters of the alphabet and it should be written in of the original language. $\frac{\sqrt[n]{a}}{\sqrt[n]{b}} = \sqrt[n]{\frac{a}{b}}$. There is no need for special content, but the length of words should match the language. $a \sqrt[n]{b} = \sqrt[n]{a^n b}$.

Table 3.1: A table

a	b	c	d	e
f	g	h	i	j
k	l	m	n	o
p	q	r	s	t
u	v	w	x	y
z	æ	ø	å	

3.1 First section

3.1.1 First subsection with some *Math* symbol

Hello, here is some text without a meaning. This text should show what a printed text will look like at this place. $\sin^2(\alpha) + \cos^2(\beta) = 1$. If you read this text, you will get no information $E = mc^2$. Really? Is there no information? Is there a difference between this text and some nonsense like “Huardest gefburn”? Kjift – not at all! A blind text like this gives you information about the selected font, how the letters are written and an impression of the look. $\sqrt[n]{a} \cdot \sqrt[n]{b} = \sqrt[n]{ab}$. This text should contain all letters of the alphabet and it should be written in of the original language. $\frac{\sqrt[n]{a}}{\sqrt[n]{b}} = \sqrt[n]{\frac{a}{b}}$. There is no need for special content, but the length of words should match the language. $a \sqrt[n]{b} = \sqrt[n]{a^n b}$.

- item1
- item2
- ...

3.1.2 Mathematics

Hello, here is some text without a meaning. $d\Omega = \sin \vartheta d\vartheta d\varphi$. This text should show what a printed text will look like at this place. If you read this text, you will get no information. Really? Is there no information? Is there a difference between this text and some nonsense like “Huardest gefburn”? Kjift – not at all! A blind text like this gives you information about the selected font, how the letters are written and an impression of the look. $\sin^2(\alpha) + \cos^2(\beta) = 1$. This text should contain all letters of the alphabet and it should be written in of the original language $E = mc^2$. There is no need for special content, but the length of words should match the language. $\sqrt[n]{a} \cdot \sqrt[n]{b} = \sqrt[n]{ab}$.

Proposition 3.1. *A proposition... (similar environments include: theorem, corollary, conjecture, lemma)*

Proof. And its proof. □

3.1.3 Source code example

Algorithm 3.1 The Hello World! program in Java.

```
class HelloWorldApp {  
    public static void main(String[] args) {  
        //Display the string  
        System.out.println("Hello World!");  
    }  
}
```

You can refer to figures using the predefined command like Figure 3.1, to pages like page 14, to tables like Table 3.1, to chapters like Chapter ?? and to sections like Section 3.1 and you may define similar commands to refer to proposition, algorithms etc.