VILNIUS UNIVERSITY

FACULTY OF MATHEMATICS AND INFORMATICS

SOFTWARE ENGINEERING STUDY PROGRAMME

Documentation

Analysis of Human Benchmark System

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Summary

Summary in english.

Keywords: work related keywords, with a ***minimum of 3 keywords***, but can be more.

Santrauka

Darbo santrauka.

Raktiniai žodžiai: čia surašomi su darbu susiję raktiniai žodžiai, ***minimalus raktinių žodžių kiekis - 3***, tačiau jų gali būti ir daugiau.

List of Figures

1 figure Figure numbers are at the bottom, caption is at the bottom 15

List of Tables

1 table Tables are numbered at the top, caption is at the top 14

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List of symbols

This section is for when symbols are used. For example:

- $\mathbb{E}\,X$ denotes the mean of the random variable X.

List of abbreviations

This section is for when abbreviations are used. For example:

u.d.i.r.v.	uniformly distributed independent random variables

Introduction

For any written work, you must refer to the methodology guidelines of the respective study programme[1]. These contain all the guidelines for citations, structure, length, etc.

[1]The latest methodology requirements for all programmes can be found here, in the respective programme: `https://mif.vu.lt/lt3/en/studies/bachelor-studies`

1 Formatting

This section will give you examples of how to format mathematical text, tables and figures, and describe how to correctly formulate the mathematical results of your final thesis.

1.1 Mathematical text

Mathematical formulas can be embedded in paragraphs of text by separating the formulas LaTeX code with `$...$`. Example: trigonometric identity $\sin^2\alpha + \cos^2\alpha = 1$.

However, formulas will look much nicer if they are separated into separate equations by placing the formula code in the environment `\[...\]`. Example of an equation:

$$\mathrm{e}^{i\alpha} = \cos\alpha + i\sin\alpha, \qquad \alpha \in \mathbb{R}.$$

The mathematical symbols $\mathbb{R}$ and e have been used in this equation, with the commands `\RR` and `\ee` defined at the beginning of this template. Sometimes formulas take several lines, e.g.:

$$\begin{aligned} 2 = 1 + 1 + 0 &= \left(\frac{\sqrt{16}}{\tan^2\pi/3 + 1}\right) + \ln\mathrm{e} + \sin\pi \\ &= (\sin^2 17 + \cos^2 17)^{\ln\mathrm{e}} + \cos 0 + (x^{1/\ln x})'. \end{aligned} \tag{1}$$

Don't forget to put a full stop (.) at the end of the formula if it is the end of a sentence. Also note the height of brackets with a large fraction inside `\frac`, which is automatically adjusted with `\left( ... \right)` or specified with `\big`, `\Big`, `\bbig`.

If the formula is needed later, it does not need to be rewritten each time. You can always quote the formula you need with the `\eqref` command. For example, the formula with the number above is quoted as follows: equation (1). To do this, the `\label` command must assign a temporary name to the formula, which LaTeX will automatically change to the required number. More information on LaTeX mathematical symbols, equations, mathematical environments and commands can be found in this document [12].

Here are some more formulas that use more complex mathematical commands. Matrices and determinants are written using the LaTeX environments `pmatrix` and `vmatrix`:

$$A = \begin{pmatrix} 0 & 1 \\ 2 & 3 \end{pmatrix}, \qquad \det A = \begin{vmatrix} 0 & 1 \\ 2 & 3 \end{vmatrix} = 0 \cdot 3 - 1 \cdot 2 = -2.$$

For more complex equations and matrices, the `mathtools` [2] commands are very useful. The `mathtools` package is included in the working template, so you can use its commands directly.

The derivative is written using an apostrophe character (`'`), for example,

$$(f(x)g(x))' = f'(x)g(x) + f(x)g'(x).$$

Taylor polynomial:

$$p(x) = p(a) + p'(a)(x-a) + \frac{p''(a)}{2!}(x-a)^2 + ... + \frac{p^{(n)}}{n!}(x-a)^n.$$

For writing simple and partial derivatives, differentials, gradients, etc., the template includes the very handy commands `\dv` and `\pdv`, `\dd`, `\grad` from the `physics` package [1]:

$$\frac{\mathrm{d}f}{\mathrm{d}x}, \qquad \frac{\mathrm{d}^2 f}{\mathrm{d}x^2}, \qquad \frac{\partial f}{\partial x}, \qquad \frac{\partial^5 f}{\partial x^5} \qquad \frac{\partial^2 f}{\partial x \partial y}, \qquad \mathrm{d}f\,, \qquad \boldsymbol{\nabla} f$$

To write the integral in an interval, use the LaTeXcommand `\int_{a}^{b}`:

$$\int_a^b f(x)\mathrm{d}x = F(a) - F(b) = \left. F(x) \right|_a^b$$

For writing multiple, surface, curvilinear integrals you can use the commands `\iint`, `\iiint`, `\oint`, etc.

$$\iint_D f(x,y)\,\mathrm{d}x\,\mathrm{d}y\,, \quad \iint_D f(x,y)\,\mathrm{d}S\,, \quad \int_\gamma f(x,y)\,\mathrm{d}l\,, \quad \oint_\gamma P(x,y)\,\mathrm{d}x + Q(x,y)\,\mathrm{d}y\,.$$

1.2 Matematinių rezultatų formulavimas

To formulate the mathematical results of your work, you should use environments

Definition, *Proposition*, *Theorem*, *Lemma*,

Corollary, *Remark*, *Example*, *Proof*.

These environments are already defined in your thesis template `VUMIFTemplateClass.cls`, by combining the standard LaTeX commands

`definition`, `proposition`, `theorem`, `lemma`,

`corollary`, `remark`, `example`, `proof`.

Example of a definition:

1.2.1 Definition. A number $p \in \mathbb{N}$ is called a *prime number* if it is divisible only by 1 and itself. The set of prime numbers is denoted by $\mathbb{P}$.

Example of a proposition:

1.2.2 Proposition. *The average of the product of two independent random variables $X, Y : \Omega \to \mathbb{R}$ is equal to the product of the averages of the two original variables XY:*

$$\mathbb{E}\,(XY) = \int_\Omega X(\omega)Y(\omega)\mathrm{d}\mu(\omega) = \mathbb{E}\,X \cdot \mathbb{E}\,Y,$$

provided that the means of X, Y and XY exist.

Important mathematical statements are called *theorems*:

1.2.3 Theorem (First theorem on isomorphism)**.** *Suppose that $f : G \to H$ is a homomorphism between the groups G and H. Then the image $f(G)$ of the group G is isomorphic to the factor group $G/\ker(f)$, that is*

$$f(G) \cong G/\ker(f).$$

The shorter auxiliary statements are called *lemmas*. However, lemma formulations can also be quite complex:

1.2.4 Lemma (Vector substitution lemma)**.** *Suppose that the vectors of the linear space V over the body k*

$$v_1, v_2, \ldots, v_s \tag{2}$$

are linearly independent, and that each vector v_i, $1 \le i \le s$ of this family is linearly expressed in vectors

$$w_1, w_2, \ldots, w_t. \tag{3}$$

Then $s \le t$, and there exists a subfamily $w_{j_1}, w_{j_2}, ..., w_{j_s}$ of the vector family (3)*, which we replace by the vectors $v_1, v_2, ..., v_s$, we get a family of vectors* (3) *equivalent to the family* (3)*.*

The *Remark* environment is for small remarks:

1.2.5 Remark. The condition of the theorem that the interval $[a, b]$ is compact and the function $f(x)$ is continuous on that interval is essential.

Another environment *Example* is used for short numerical or formula examples:

1.2.6 Example. Systems of equations

$$\begin{cases} ax + by = e \\ cx + dy = f \end{cases}$$

Kramer's formula for solutions:

$$x = \frac{D_x}{D}, \qquad y = \frac{D_y}{D},$$

here

$$D = \begin{vmatrix} a & b \\ c & d \end{vmatrix} = ad - bc, \qquad D_x = \begin{vmatrix} e & b \\ f & d \end{vmatrix} = ed - bf, \qquad D_y = \begin{vmatrix} a & e \\ c & f \end{vmatrix} = af - ec.$$

The `proof` syntax is used to record evidence. Below is a proposition and a proof of that proposition. The end of the proof is automatically marked with the □ symbol by LaTeX.

1.2.7 Proposition. *A square matrix A is non-singular if and only if* $\det A \neq 0$*.*

Proof. If A is non-singular, then there exists a matrix B such that $AB = I$. By the determinant property of the product of matrices,

$$\det A \cdot \det B = \det AB = \det I = 1.$$

Therefore, $\det A \neq 0$. Now suppose that $\det A \neq 0$. Let A^* be a transposed adjoint matrix. Then:

$$AA^* = \begin{pmatrix} a_{11} & \dots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{n1} & \dots & a_{nn} \end{pmatrix} \cdot \begin{pmatrix} A_{11} & \dots & A_{n1} \\ \vdots & \ddots & \vdots \\ A_{1n} & \dots & A_{nn} \end{pmatrix} = \begin{pmatrix} \det A & \dots & 0 \\ 0 & \ddots & 0 \\ 0 & \dots & \det A \end{pmatrix}$$

$$= \det A \cdot \begin{pmatrix} 1 & \dots & 0 \\ 0 & \ddots & 0 \\ 0 & \dots & 1 \end{pmatrix} = \det A \cdot I.$$

So, $A \cdot A^* = \det A \cdot I$. Dividing both sides of the identity by the $\det A \neq 0$ gives $A \cdot \left(\frac{1}{\det A} A^*\right) = I$. Similarly, we can show that $\left(\frac{1}{\det A} A^*\right) \cdot A = I$. Hence, $\frac{1}{\det A} A^*$ is the inverse of the matrix A, and hence A is non-singular. □

Please note that mathematical environments are numbered automatically. Like formulas, mathematical definitions, statements, examples can be cited elsewhere in the text by first naming them with `\label` and then creating a citation reference `\ref` at the appropriate place. For example, we can quote Theorem 1.2.3 or Lem 1.2.4 in the places in the text where we need to refer to them.

1.3 Tables

If tables are presented, the table references should be mentioned in the text, for example: the 1 table. table shows some results.

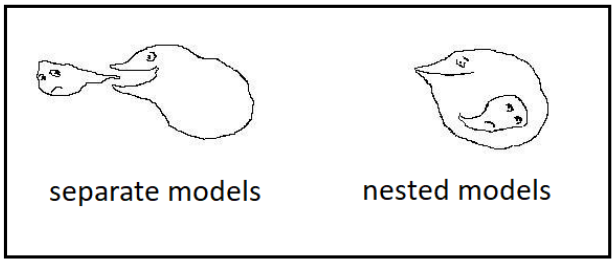
1 table. *Tables are numbered at the top, caption is at the top*

Column 1	Column 2	Column 3

Each table must have a title, which, like the table number, must appear on the same line above the table. All tables shall be numbered consecutively (letter numbering is not recommended, e.g. Table 7a).

1.4 Images, graphs, charts, photos

If figures are used in the work, they must be mentioned in the text, e.g.: 1 figure. figure shows an example of how to present a figure.



1 figure. *Figure numbers are at the bottom, caption is at the bottom*

Below is the text after the image.

1.5 Lists

Example of a non-numbered list:

- first element;
- second element.

Example of a numbered lists:

1. lorem ipsum dolor sit amet;
2. consectetur adipiscing elit;
3. vivamus a nisl gravida.

2 Presentation of software code

This section outlines the way in which software code can be presented.

2.1 Algorithms

Algorithms are numbered in the same way as figures or tables. They must be mentioned in the text, e.g.: 1 algorithm is used to find the minimum value of the function $\mathcal{L}$.

1 algorithm Gradual descent pseudocode

```
# We assume that ℒ is defined in the text
Input: 𝒟 – dataset
Input: θ_0 – initializing random values for parameters
Input: γ – learning rate, step size
Input: m – number of epochs
for i = 1, 2, ..., m do
    θ_i := θ_{i−1} − γ∇_θ ℒ(𝒟, θ_{i−1})
    # The derivative of function ℒ is calculated automatically by autograd
end for
```

2.1.1 Subsubsection example

No need to use lots of *subsubsections*.

Results and conclusions

For details of what needs to be written in this section, please refer to the methodology requirements of the respective programme.

References and sources

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Appendix 1. Examples of citations

In the document *bibliography.bib*, you need to add all the cited sources and after using the function *{\cite{name of the cited object}}* the corresponding source will be added to the list of literature sources.

bibliography.bib provides examples of some of the most commonly cited types of sources:

- web pages (*@online*) [11],
- datasets (*@dataset*) [8]
- articles (*@article*) [5, 14],
- articles from conferences (*@inproceedings*) [9, 17],
- books (*@book*) [6, 15],
- theses (*@thesis or mastersthesis/phdthesis* [10, 13])
- electronic publications (*@misc*) [7, 16]

Examples are also provided for ChatGPT citation, both in general [3] and for a specific conversation [4].