FACULTY
OF INFORMATION
TECHNOLOGY
CTU IN PRAGUE

Assignment of master's thesis

Title:	A system for signals manipulation on the automotive ethernet
Student:	Bc. Oleksandr Korotetskyi
Supervisor:	Ing. Martin Štěpánek
Study program:	Informatics
Branch / specialization:	Software Engineering
Department:	Department of Software Engineering
Validity:	until the end of summer semester 2023/2024

Instructions

To test automotive control units, it is mandatory to simulate all the necessary values/ states of the input signals that are sent in Ethernet packets (frames). In some cases, it is easier to manipulate with data and simulate all the states directly in the packet than to use the simulation of other control units.

1) Perform research on signals and SAE levels in automotive ethernet
2) Perform research on possibilities of manipulation with data in ethernet packet and data security
3) Collect RQ for the test system
4) Design SW architecture
5) Design and implement SW for signal manipulation
6) Design a test strategy for the developed SW
7) Perform the test of implemented SW
8) Implementation should be done on Linux OS

Electronically approved by Ing. Michal Valenta, Ph.D. on 17 January 2023 in Prague.

Master’s thesis

A SYSTEM FOR SIGNALS MANIPULATION ON THE AUTOMOTIVE ETHERNET

Ing. Oleksandr Korotetskyi

Faculty of Information Technology
Department of Software Engineering
Supervisor: Ing. Martin Štěpánek
March 27, 2023

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Declaration

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Abstract

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Abstrakt

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Summary

Summary section

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Abbreviations

ACC	Adaptive Cruise Control
ADS	Autonomous Driving System
ADS-DV	Automated Driving System-Dedicated Vehicle
ASS	Active Safety System
DAS	Driving Automation System
SAE	Society of Automotive Engineers
OBD	On-Board Diagnostics
CAN	Controller Area Network
ISO	International Organization for Standardization
ISO-TP	ISO Transport Protocol
DDT	Dynamic driving task
ODD	Operational design domain
OEDR	Object and Event Detection and Response

Introduction

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A survey of the American National Highway Traffic Safety Administration (NHTSA) reports that nearly 94% of road accidents are due to human errors [1]. These human-related mistakes are mainly classified as driver distraction, drunk or otherwise impaired driving, lack of attention, violation of the traffic rules, limited view of traffic conditions, and jay-walking pedestrians [2]. The lack of rule obedience, the increasing number of vehicles on roads, and improper road culture have therefore motivated officials, manufacturers, and legislators to make substantial improvements in transportation systems. There are growing research and development attempts to enhance safety and automation capability of autonomous vehicles (AVs), prevent traffic accidents, and create a better road infrastructure. The potential benefits of AVs are improved convenience, operational safety (especially for seniors and people with reduced mobility) [3], reduced CO2 emissions [4], diminished transportation costs [5], improved safety [6, 7], and reduced traffic density [8].

0.1 Motivation

0.2 Problem Statement & Objectives

0.3 Delimitations

0.4 Research Questions & Methodology

0.5 Thesis Outline

Chapter 1

II: ADRIANA (Preliminaries)

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This chapter provides a theoretical background required for understanding of the thesis' problematics and accomplishing the tasks set. It contains a general overview of the current state of driving automation, including a detailed taxonomy and comparison of the various levels of automation. It is important to specify, that the focus is being made mainly on the very *taxonomy* without going into the details of processes, interactions of conditional constituents & techologies coherent with each level individually.

Later, the analysis of mechanisms that make the driving automation possible (inter-ECUs communication) is being done, exploring the various communication protocols and standards. The focus is being made on possibilities of data manipulation & security issues that might be useful in the terms of pending implementation of the system for signals manipulation on the Automotive Ethernet.

1.1 Taxonomy of Driving Automation

In order to dive into the topic of driving automation, the *driving* itsef should be overviewed at first.

Driving entails a variety of decisions and actions, which may or may not involve a vehicle being in motion, or even being in an active lane of traffic. The overall act of driving can be divided into three types of driver effort: strategic, tactical, and operational (Michon, 1985).

Strategic effort involves trip planning, such as deciding whether, when and where to go, how to travel, best routes to take, etc.

Tactical effort involves maneuvering the vehicle in traffic during a trip, including deciding whether and when to overtake another vehicle or change lanes, selecting an appropriate speed, checking mirrors, etc.

Operational effort involves split-second reactions that can be considered pre-cognitive or innate, such as making-micro-corrections to steering, braking and accelerating to maintain lane position in traffic or to avoid a sudden obstacle or hazardous event in the vehicle's pathway.

The schematic view of the driving task can be seen in Figure 1.1.

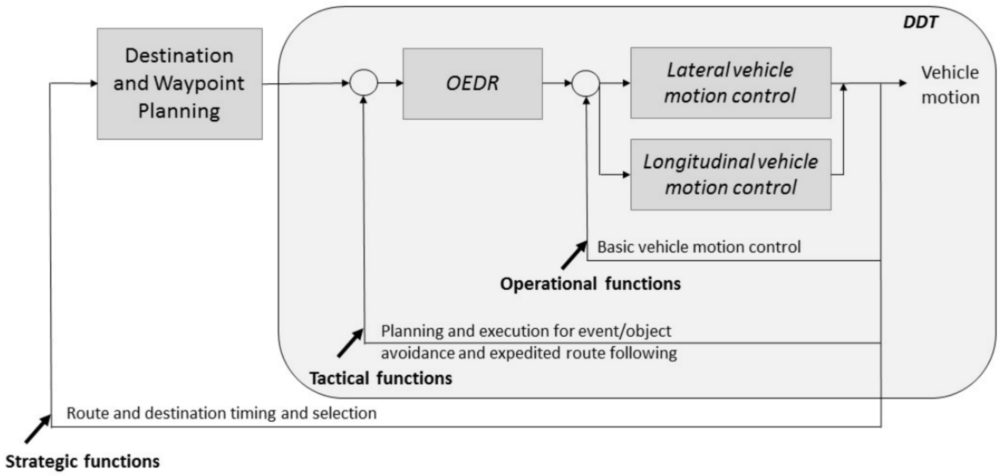

Figure 1.1 Schematic (not a control diagram) view of the driving task.

A self-driving car, also known as an *autonomous car*, is a car that is capable of traveling without human input [1]. Self-driving cars use sensors to perceive their surroundings, such as optical and thermographic cameras, radar, lidar, ultrasound/sonar, GPS, odometry and inertial measurement units [2]. Also, further technologies used to achieve autonomous driving might include several forms of artificial intelligence [3].

Researchers **forecast** that by 2025 approximately 8 million autonomous or semi-autonomous vehicles will be used on the road. Before merging onto roadways, self-driving cars will first have to progress through several levels of driver assistance technology advancements.

SAE J3016 defines 6 levels of automation, sketching an incremental evolution from no automation to fully autonomous vehicles [4]. Central to this taxonomy are the respective roles of the (human) *user* and the *driving automation system* (DAS) in relation to each other. Since changes in the functionality of a *driving automation system* change the role of the (human) *user*, they provide a basis for categorizing such system *features*. For example:

- If the driving automation system performs the sustained longitudinal and/or lateral vehicle motion control subtasks of the DDT [1], the driver does not do so, although s/he is expected to complete the DDT. This division of roles corresponds to Levels 1 and 2.
- If the driving automation system performs the entire DDT, the user does not do so. However,

[1] All of the real-time operational and tactical functions required to operate a vehicle in on-road traffic, excluding the strategic functions such as trip scheduling and selection of destinations and waypoints, and including, without limitation, the following subtasks:

1. Lateral vehicle motion control via steering (operational).
2. Longitudinal vehicle motion control via acceleration and deceleration (operational).
3. Monitoring the driving environment via object and event detection, recognition, classification, and response preparation (operational and tactical).
4. Object and event response execution (operational and tactical).
5. Maneuver planning (tactical).
6. Enhancing conspicuity via lighting, sounding the horn, signaling, gesturing, etc. (tactical)

if a DDT fallback-ready user is expected to take over the DDT when a DDT performance-relevant system failure occurs or when the driving automation system is about to leave its operational design domain (ODD)[2], then that user is expected to be receptive and able to resume DDT performance when alerted to the need to do so. This division of roles corresponds to Level 3.

- Lastly, if a driving automation system can perform the entire DDT and DDT fallback either within a prescribed ODD (Level 4) or in all driver-manageable on-road operating situations (Level 5) then any users present in the vehicle while the ADS is engaged are passengers.

Although the vehicle fulfills a role in this driving automation taxonomy, it does not change the role of the user in performing the DDT. By contrast the role played by the driving automation system complements the role of the user in performing the DDT, and in that sense changes it.

In this way, driving automation systems are categorized into levels based on:

1. Whether the driving automation system performs either the longitudinal or the lateral vehicle motion control subtask of the DDT.

2. Whether the driving automation system performs both the longitudinal and the lateral vehicle motion control subtasks of the DDT simultaneously.

3. Whether the driving automation system also performs the OEDR subtask of the DDT.

4. Whether the driving automation system also performs DDT fallback.

5. Whether the driving automation system is limited by an ODD.

Table 1 summarizes the six levels of driving automation in terms of these five elements. It is worth mentioning, that SAE's levels of driving automation are descriptive and informative, rather than normative, and technical rather than legal. Elements indicate minimum rather than maximum capabilities for each level [5].

In this table, "system" refers to the driving automation system or ADS, as appropriate. Definitions of some terms that seem to be obvious ("driver", for instacne) are omitted for the sake of brevity. In addition, as it was implicitly mentioned earlier, the DDT does not include strategic aspects of the driving task, such as determining destination(s) and deciding when to travel.

► Note 1.1. *"Unconditional/not ODD-specific"* means that the ADS can operate the vehicle on-road anywhere within its region of the world and under all road conditions in which a conventional vehicle can be reasonably operated by a typically skilled human driver. This means, for example, that there are no design-based weather, time-of-day, or-geographical restrictions on where and when the ADS can operate the vehicle. However, there may be conditions not manageable by a driver in which the ADS would also be unable to complete a given trip (e.g., white-out snow storm, flooded roads, glare ice, etc.) until or unless the adverse conditions clear. At the onset of such unmanageable conditions the ADS would perform the DDT fallback to achieve a minimal risk condition (e.g., by pulling over to the side of the road and waiting for the conditions to change).

Figure 1.1 illustrates how a trip could be completed by use of various combinations of driving automation features engaged at different levels of driving automation.

[2]Specified by manufacturer.

	Level	Name	Narrative Definition	DDT		DDT Fallback	ODD
				Sustained Lateral and Longitudinal Vechicle Motion Control	**OEDR**		
Driver Performs Part or All of the DDT							
	0	*No Driving Automation*	The performance by the driver of the entire DDT, even when enchaned by ASSs.	Driver	Driver	Driver	n/a
Driver Support	**1**	*Driver Assistance*	The sustained and ODD-specific execution by a DAS of either the lateral or longitudinal vehicle motion control subtask of the DDT (but not both simultaneously) with the expectation that the driver performs the remainder of the DDT.	Driver and System	Driver	Driver	Limited
Driver Support	**2**	*Partial Driving Automation*	The sustained and ODD-specific execution by a DAS of both the lateral and longitudinal vehicle motion control subtasks of the DDT with the expectation that the driver completes the OEDR subtask and supervises the DAS.	System	Driver	Driver	Limited
ADS Performs the Entire DDT (While Enabled)							
Automated Driving	**3**	*Conditional Driving Automation*	The sustained and ODD-specific performance by an ADS of the entire DDT with the expectation that the DDT fallback-ready user is receptive to ADS-issued requests to intervene, as well as to DDT performance-relevant system failures in other vehicle systems, and will respond appropriately.	System	System	Fallback-Ready User (becomes the driver during the fallback)	Limited
Automated Driving	**4**	*High Driving Automation*	The sustained and ODD-specific performance by an ADS of the entire DDT and DDT fallback without any expectation that a user will need to intervene.	System	System	System	Limited
Automated Driving	**5**	*Full Driving Automation*	The sustained and unconditional (i.e., not ODD-specific) performance by an ADS of the entire DDT and DDT fallback wothout any expectation that a user will need to intervene.	System	System	System	Unlimited*

Table 1.1 Summary of levels of driving automation according to SAE J3016.

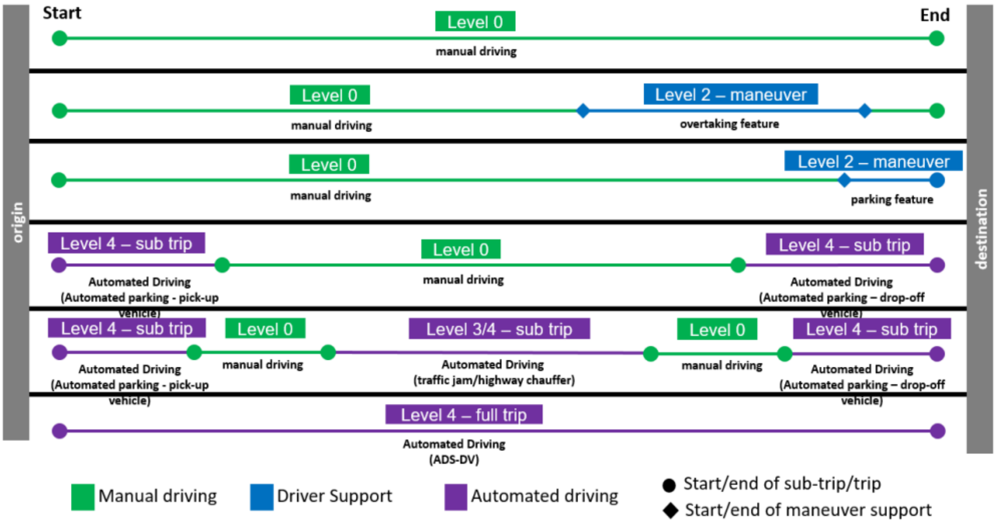

Figure 1.2 Examples of driving automation system features/types that could be available during a given trip.

1.2 Internal Networks

1.3 Controller Area Network (CAN)

1.3.1 J1939

1.3.2 OBD2

1.3.3 LIN (Local Interconnect Network)

1.3.4 UDS (Unified Diagnostic Services)

1.4 CAN Bus Errors

1.5 Data Manipulation & Security

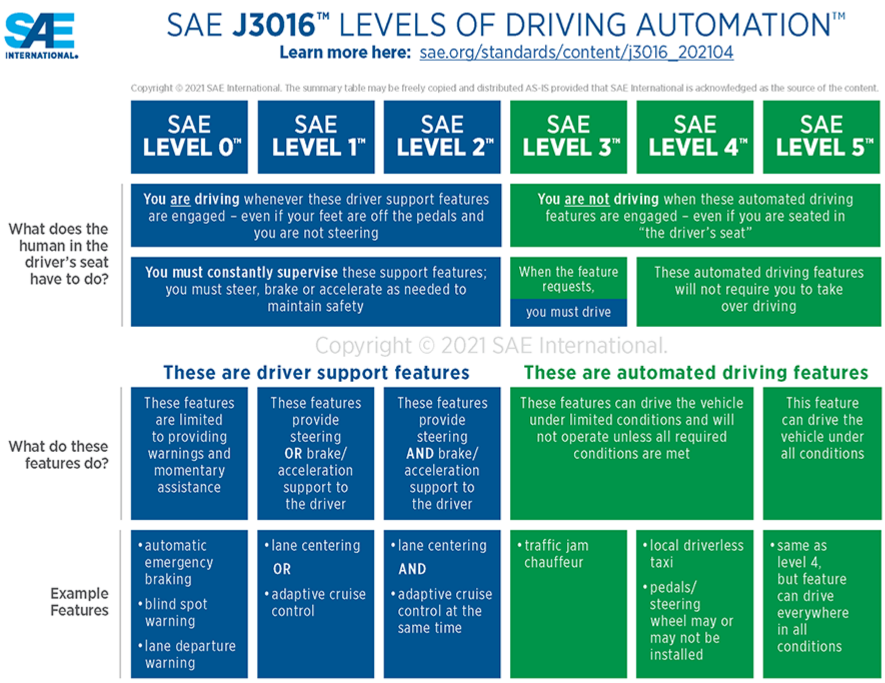

Figure 1.3 SAE J3016

Chapter 2

III: BEATRIX (Testing System Requirements)

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2.1 Software Requirements

2.2 Hardware Requirements

Chapter 3

IV: CALEDONIA

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3.1 Ut enim ad minim veniam

Chapter 4

V: DELORES

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4.1 Ut enim ad minim veniam

Chapter 5

VI: RESULTS

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5.1 Ut enim ad minim veniam

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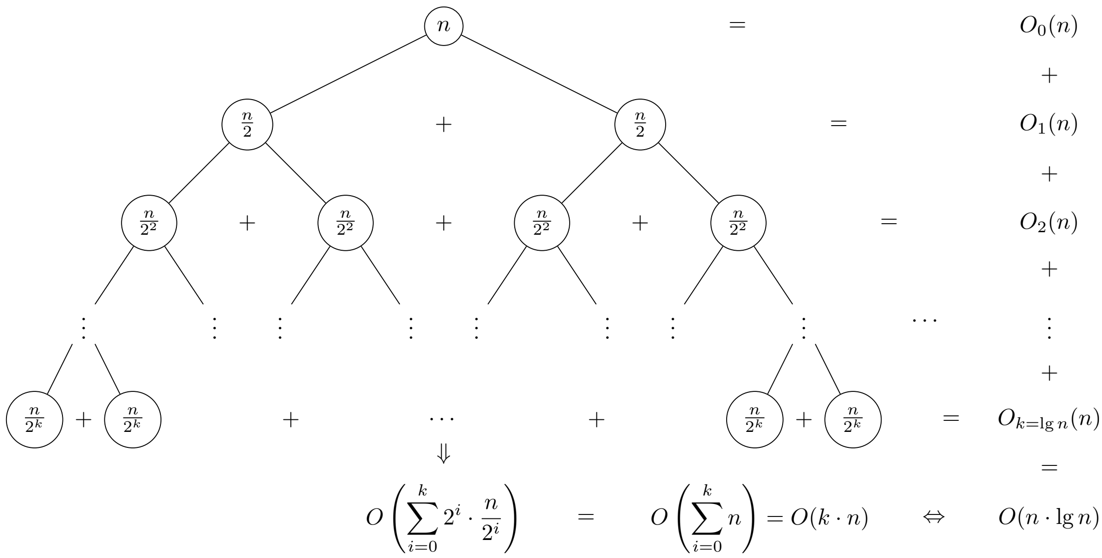

Figure 5.1 Lorem ipsum dolor sit amet

sapien turpis, fermentum vel, eleifend faucibus, vehicula eu, lacus.

5.2 Ut enim ad minim veniam

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Nulla malesuada porttitor diam. Donec felis erat, congue non, volutpat at, tincidunt tristique, libero. Vivamus viverra fermentum felis. Donec nonummy pellentesque ante. Phasellus adipiscing semper elit. Proin fermentum massa ac quam. Sed diam turpis, molestie vitae, placerat a, molestie nec, leo. Maecenas lacinia. Nam ipsum ligula, eleifend at, accumsan nec, suscipit a, ipsum. Morbi blandit ligula feugiat magna. Nunc eleifend consequat lorem. Sed lacinia nulla vitae enim. Pellentesque tincidunt purus vel magna. Integer non enim. Praesent euismod nunc eu purus. Donec bibendum quam in tellus. Nullam cursus pulvinar lectus. Donec et mi. Nam vulputate metus eu enim. Vestibulum pellentesque felis eu massa.

Quisque ullamcorper placerat ipsum. Cras nibh. Morbi vel justo vitae lacus tincidunt ultrices. Lorem ipsum dolor sit amet, consectetuer adipiscing elit. In hac habitasse platea dictumst. Integer tempus convallis augue. Etiam facilisis. Nunc elementum fermentum wisi. Aenean placerat. Ut imperdiet, enim sed gravida sollicitudin, felis odio placerat quam, ac pulvinar elit purus eget enim. Nunc vitae tortor. Proin tempus nibh sit amet nisl. Vivamus quis tortor vitae risus porta vehicula.

5.2.1 Ut enim ad minim veniam

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5.3 Class aptent taciti

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5.3.1 Class aptent taciti

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      i. Ut enim
      ii. Ut enim
         A. Ut enim
         B. Ut enim

Code listing 5.1 Zbytečný kód

```
#include<stdio.h>
#include<iostream>
// A comment
int main(void)
{
    printf("Hello␣World\n");
    return 0;
}
```

Table 5.1 Zadávání matematiky

Typ	Prostředí	LaTeXovská zkratka	TeXovská zkratka
Text	`math`	`\(...\)`	`$...$`
Displayed	`displaymath`	`\[...\]`	`$$...$$`

5.4 Ut enim ad minim veniam, quis nostrud

Ut enim ad minim veniam, quis nostrud exercitation ullamco laboris nisi ut aliquip ex ea commodo consequat. Nulla non arcu lacinia neque faucibus fringilla. Vestibulum erat nulla, ullamcorper nec, rutrum non, nonummy ac, erat. Aliquam erat volutpat. Proin pede metus, vulputate nec, fermentum fringilla, vehicula vitae, justo.[1] Etiam dictum tincidunt diam. In laoreet, magna id viverra tincidunt, sem odio bibendum justo, vel imperdiet sapien wisi sed libero. Nulla est. Maecenas fermentum, sem in pharetra pellentesque, velit turpis volutpat ante, in pharetra metus odio a lectus. Duis aute irure dolor in reprehenderit in voluptate velit esse cillum dolore eu fugiat nulla pariatur.

Nullam feugiat, turpis at pulvinar vulputate, erat libero tristique tellus, nec bibendum odio risus sit amet ante. Aenean id metus id velit ullamcorper pulvinar. Fusce wisi. Integer lacinia. Aliquam id dolor. Pellentesque pretium lectus id turpis. Suspendisse sagittis ultrices augue. In laoreet, magna id viverra tincidunt, sem odio bibendum justo, vel imperdiet sapien wisi sed libero. Sed ac dolor sit amet purus malesuada congue. [6]

Class aptent taciti sociosqu ad litora torquent per conubia nostra, per inceptos hymenaeos. Fusce suscipit libero eget elit. Etiam dui sem, fermentum vitae, sagittis id, malesuada in, quam. Aliquam id dolor. Curabitur bibendum justo non orci. Duis viverra diam non justo. Curabitur ligula sapien, pulvinar a vestibulum quis, facilisis vel sapien. Duis condimentum augue id magna semper rutrum. Aliquam ornare wisi eu metus. Fusce aliquam vestibulum ipsum. Vivamus ac leo pretium faucibus. [7]

5.4.1 Ut enim ad minim veniam, quis nostrud

Ut enim ad minim veniam, quis nostrud exercitation ullamco laboris nisi ut aliquip ex ea commodo consequat. Nulla non arcu lacinia neque faucibus fringilla. Vestibulum erat nulla, ullamcorper nec, rutrum non, nonummy ac, erat. Aliquam erat volutpat. Proin pede metus, vulputate nec, fermentum fringilla, vehicula vitae, justo. Etiam dictum tincidunt diam. In laoreet, magna id viverra tincidunt, sem odio bibendum justo. [**Sestakova2018**]

Nulla est. Maecenas fermentum, sem in pharetra pellentesque, velit turpis volutpat ante, in pharetra metus odio a lectus. Duis aute irure dolor in reprehenderit in voluptate velit esse cillum dolore eu fugiat nulla pariatur. Nullam feugiat, turpis at pulvinar vulputate, erat libero tristique tellus, nec bibendum odio risus sit amet ante. Aenean id metus id velit ullamcorper pulvinar.

[1] Ut enim ad minim veniam, quis nostrud exercitation.

5.4.1.1 Class aptent taciti

▶ **Definice 5.1** (Optional label)**.** *Class aptent taciti sociosqu ad litora torquent per conubia nostra, per inceptos hymenaeos. Fusce suscipit libero eget elit. Etiam dui sem, fermentum vitae, sagittis id, malesuada in, quam. Aliquam id dolor. Curabitur bibendum justo non orci.*

▶ **Příklad 5.2.** Class aptent taciti sociosqu ad litora torquent per conubia nostra, per inceptos hymenaeos. Fusce suscipit libero eget elit. Etiam dui sem, fermentum vitae, sagittis id, malesuada in, quam. Aliquam id dolor. Curabitur bibendum justo non orci.

▶ **Věta 5.3.** *Class aptent taciti sociosqu ad litora torquent per conubia nostra, per inceptos hymenaeos. Fusce suscipit libero eget elit. Etiam dui sem, fermentum vitae, sagittis id, malesuada in, quam. Aliquam id dolor. Curabitur bibendum justo non orci.*

Proof. Fusce suscipit libero eget elit. Etiam dui sem, fermentum vitae, sagittis id, malesuada in, quam. Aliquam id dolor. Curabitur bibendum justo non orci. ◀

▶ **Důsledek 5.4.** *Fusce suscipit libero eget elit. Etiam dui sem, fermentum vitae, sagittis id, malesuada in, quam. Aliquam id dolor. Curabitur bibendum justo non orci.*

▶ **Návrh 5.5.** *Fusce suscipit libero eget elit. Etiam dui sem, fermentum vitae, sagittis id, malesuada in, quam. Aliquam id dolor. Curabitur bibendum justo non orci.*

▶ Note 5.6. Fusce suscipit libero eget elit. Etiam dui sem, fermentum vitae, sagittis id, malesuada in, quam. Aliquam id dolor. Curabitur bibendum justo non orci.

▶ Remark 5.7. Fusce suscipit libero eget elit. Etiam dui sem, fermentum vitae, sagittis id, malesuada in, quam. Aliquam id dolor. Curabitur bibendum justo non orci.

▶ **Tvrzení 5.8.** *Class aptent taciti sociosqu ad litora torquent per conubia nostra, per inceptos hymenaeos. Fusce suscipit libero eget elit. Etiam dui sem, fermentum vitae, sagittis id, malesuada in, quam. Aliquam id dolor. Curabitur bibendum justo non orci.*

Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Ut purus elit, vestibulum ut, placerat ac, adipiscing vitae, felis. Curabitur dictum gravida mauris. Nam arcu libero, nonummy eget, consectetuer id, vulputate a, magna. Donec vehicula augue eu neque. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Mauris ut leo. Cras viverra metus rhoncus sem. Nulla et lectus vestibulum urna fringilla ultrices. Phasellus eu tellus sit amet tortor gravida placerat. Integer sapien est, iaculis in, pretium quis, viverra ac, nunc. Praesent eget sem vel leo ultrices bibendum. Aenean faucibus. Morbi dolor nulla, malesuada eu, pulvinar at, mollis ac, nulla. Curabitur auctor semper nulla. Donec varius orci eget risus. Duis nibh mi, congue eu, accumsan eleifend, sagittis quis, diam. Duis eget orci sit amet orci dignissim rutrum.

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5.4.2 Class aptent taciti sociosqu

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Chapter 6
Lorem ipsum

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6.1.1 Class aptent taciti

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Nulla malesuada porttitor diam. Donec felis erat, congue non, volutpat at, tincidunt tristique, libero. Vivamus viverra fermentum felis. Donec nonummy pellentesque ante. Phasellus adipiscing semper elit. Proin fermentum massa ac quam. Sed diam turpis, molestie vitae, placerat a, molestie nec, leo. Maecenas lacinia. Nam ipsum ligula, eleifend at, accumsan nec, suscipit a, ipsum. Morbi blandit ligula feugiat magna. Nunc eleifend consequat lorem. Sed lacinia nulla vitae enim. Pellentesque tincidunt purus vel magna. Integer non enim. Praesent euismod nunc eu purus. Donec bibendum quam in tellus. Nullam cursus pulvinar lectus. Donec et mi. Nam vulputate metus eu enim. Vestibulum pellentesque felis eu massa.

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Appendix A
Nějaká příloha

Sem přijde to, co nepatří do hlavní části.

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Obsah přiloženého média

```
readme.txt ............................ stručný popis obsahu média
exe ......................... adresář se spustitelnou formou implementace
src
  impl ................................. zdrojové kódy implementace
  thesis ................... zdrojová forma práce ve formátu LaTeX
text ........................................................ text práce
  thesis.pdf ............................. text práce ve formátu PDF
```