

# **Komponenta výukového serveru TI – NP-úplné problémy 2**

Component of Learning Server for  
Theoretical Computer Science –  
NP-complete problems 2

Phat Tran Dai

Bakalářská práce

Vedoucí práce: Borivoj Gulas

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## Zadání bakalářské práce

Student:

**Phat Dai Tran**

Studijní program:

B0613A140014 Informatika

Téma:

**Komponenta výukového serveru TI - NP-úplné problémy 2**  
**Component of Learning Server for Theoretical Computer Science - NP-complete problems 2**

Jazyk vypracování:

čeština

Zásady pro vypracování:

V rámci diplomových a bakalářských prací vzniká výukový server pro předměty teoretické informatiky. Jedná se o sadu dynamických webových stránek umožňujících studentům pochopení různých typů úloh a problémů tím, že si mohou zadat na stránce libovolné zadání a zobrazí se jim řešení včetně postupu. Cílem této práce je vytvořit komponentu (tedy sadu webových stránek) pro výuku vybraných NP-úplných problémů a převodů mezi nimi.

1. Nastudujte si problematiku tříd složitosti problémů a s tím souvisejícím převodem mezi problémy.
2. Vytvořte dynamické webové stránky umožňující uživateli následující:
  - a) Nechat si zobrazit postupně po krocích postup algoritmu s polynomiální časovou složitostí převádějícího zadanou instanci jednoho problému na instanci jiného problému (budou implementovány alespoň 3 různé převody mezi problémy).
  - b) Zadat libovolnou instanci každého z problémů vyskytujících se v těchto převodech.
  - c) Zobrazit odpověď na otázku daného problému pro zadanou instanci, v případě kladné odpovědi i se zdůvodněním.
3. Není cílem mít co nejefektivněji implementován samotný převod, ale mít jej implementován tak, aby uživateli byla myšlenka tohoto převodu co nejsrozumitelněji ukázána.
4. Vytvořte i ukázkové vstupní instance pro implementované problémy tak, aby uživatel mohl vše vyzkoušet i bez zadávání vlastních vstupů (alespoň 5 instancí pro každý problém).

Studenti řešící toto zadání s rozdílným číslem v názvu mohou (ale nemusí) spolupracovat tak, že výsledek může mít společné uživatelské rozhraní apod. Ale každý bude implementovat jiné 3 převody mezi problémy.

Seznam doporučené odborné literatury:

- [1] Sipser, M.: Introduction to the Theory of Computation, PWS Publishing Company, 1997.
- [2] Papadimitriou, C.: Computational Complexity, Addison Wesley, 1993.
- [3] Sawa, Z.: Prezentace přednášek předmětu Teoretická informatika, dostupné online <https://www.cs.vsb.cz/sawa/ti/index.html>

Formální náležitosti a rozsah bakalářské práce stanoví pokyny pro vypracování zveřejněné na webových stránkách fakulty.

Vedoucí bakalářské práce: **Ing. Martin Kot, Ph.D.**

Datum zadání:

Datum odevzdání:

Garant studijního programu: doc. Mgr. Miloš Kudělka, Ph.D.

V IS EDISON zadáno:

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A

R

D

# Abstrakt

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# Abstract

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**Keywords:** Lorem, ipsum, dolor, sit, amet,, consectetur, adipiscing, elit,, sed, do, eiusmod, tempor, incididunt, ut, labore, et, dolore, magnam, aliquam, quaerat.

# Poděkování

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# Seznam použitých zkratek a symbolů

WTF	– What the fuck
DPC	– Do $x^2$ pice
KDPC	– Kurva do pice → aaaah

# Obsah

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# Úvod

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insolens domesticarum rerum fastidium. Non est omnino hic docendi locus; sed ita prorsus existimo, neque eum Torquatum, qui hoc primus cognomen invenerit, aut torquem illum hosti detraxisse, ut aliquam ex eo est consecutus? – Laudem et caritatem, quae sunt vitae sine metu degendae praesidia firmissima. – Filium morte multavit. – Si sine causa, nollem me ab eo delectari, quod ista Platonis, Aristoteli, Theophrasti orationis ornamenta neglexerit. Nam illud quidem physici, credere aliquid esse minimum, quod profecto numquam putavisset, si a Polyaeno, familiari suo, geometrica discere maluisset quam illum etiam ipsum dedocere. Sol Democrito magnus videtur, quippe homini erudito in geometriaque perfecto, huic pedalis fortasse; tantum enim esse omnino in nostris poetis aut inertissimae segnitiae est aut fastidii delicatissimi. Mihi quidem videtur, inermis ac nudus est. Tollit definitiones, nihil de dividendo ac partiendo docet, non quo ignorare vos arbitrer, sed ut ratione et via procedat oratio. Quaerimus igitur, quid sit extremum et ultimum bonorum, quod omnium philosophorum sententia tale debet esse.

# Heading Level 1

$$f(x) = y$$

$$\begin{pmatrix} 1 & 2 & \dots & 10 \\ 2 & 2 & \dots & 10 \\ \vdots & \vdots & \ddots & \vdots \\ 10 & 10 & \dots & 10 \end{pmatrix}$$

## 1.1 Heading Level 2

$$\Omega = \{(2, 1), (2, 1), (5, 1), (5, 1), \\ (2, 4), (2, 4), (5, 4), (5, 4), \\ (2, 4), (2, 4), (5, 4), (5, 4), \\ (2, 4), (2, 4), (5, 4), (5, 4)\}$$
$$P(B > A) = \frac{2 + 4 \cdot 2}{|\Omega|} = \frac{10}{16} = \underline{\underline{0.625}}$$

14

collaudata est, cum id, quod maxime placeat, facere possimus, omnis voluptas assumenda est, omnis dolor repellendus. Temporibus autem quibusdam et aut officiis debitis aut rerum necessitatibus saepe eveniet, ut et voluptates repudiandae sint et molestiae non recusandae. Itaque earum rerum defuturum, quas natura non depravata desiderat. Et quem ad me accedis, saluto: 'chaere,' inquam, 'Tite!' lictores, turma omnis chorusque: 'chaere, Tite!' hinc hostis mi Albucius, hinc inimicus. Sed iure Mucius. Ego autem mirari satis non queo unde hoc sit tam insolens domesticarum rerum fastidium. Non est omnino hic docendi locus; sed ita prorsus existimo, neque eum Torquatum, qui hoc primus cognomen invenerit, aut torquem illum hosti detraxisse, ut aliquam ex eo est consecutus? – Laudem et caritatem, quae sunt vitae.

## Kapitola 2

# OFDM - Orthogonal Frequency Division Multiplexing

## 2.1 Introduction

In `refKapitola 2.1`, we see how to turn Sections into Chapters. And in `refkapitole 2.1`, it is done manually.

$$\leq \pm$$

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$$\sum_{i=1}^n i = 1 + 2 + 3 + \dots + n$$

Code snippet in C programming language:

---

```
1  #include <stdio.h>
2
3  int main() {
4      printf("hello, world!\n");
5      return 0;
6  }
```

---

Výpis 1: Computer program in C language

More simple language, for example SQL:

---

```
1  SELECT
2      c.customer_id,
3      c.fname,
4      c.lname,
5      c.email
6  FROM customer c
7  WHERE EXISTS (
8      SELECT *
9      FROM purchase p
10     WHERE p.customer_id = c.customer_id
11 )
```

---

Výpis 2: Simple SQL query



## 2.2 Subheading Level 2

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$$\begin{bmatrix} 1 & * & * \\ * & 1 & * \\ * & * & 1 \end{bmatrix}$$

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## 2.3 Prokázání netranzitivity

První úkolem je ukázat, že vztahy mezi kostkami nejsou tranzitivní, to znamená, že vztahy mezi kostkami jsou tzv. cyklické<sup>1</sup>. Tvrdíme totiž, že platí  $B > A$ ,  $C > B$  a současně  $A > C$ . To znamená, že žádná kostka není „nejlepší“ ve všech případech.

Pro každou dvojici kostek vypočítáme pravděpodobnost vítězství jedné kostky nad druhou, konkrétně  $P(B > A)$ ,  $P(C > B)$  a  $P(A > C)$ , a ověříme, že všechny tyto pravděpodobnosti jsou větší než  $\frac{1}{2}$ .

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## 2.4 Subheading Level 2

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---

```

1  #show "ArtosFlow": name => box[
2    #box(image(
3      "logo.svg",
4      height: 0.7em,
5    ))
6    #name
7  ]
8
9  This report is embedded in the
10 ArtosFlow project. ArtosFlow is a
11 project of the Artos Institute.
```

---

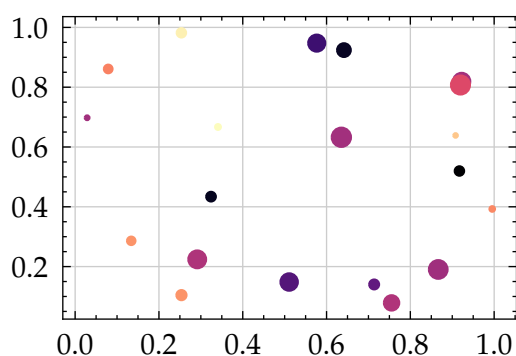
### 2.4.1 Subheading Level 3

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---

<sup>1</sup>Wikipedia, *Intransitivity*: <https://en.wikipedia.org/wiki/Intransitivity>

cum corpore dolemus, fieri tamen permagna accessio potest, si aliquod aeternum et infinitum impendere malum nobis opinemur. Quod idem licet transferre in voluptatem, ut.



Obrázek 1: Some random data visualisation

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## Kapitola 3

# Heading Level 1

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### 3.1 Subheading Level 2

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Index	Value
1	10
2	11
3	12
4	13
1	10
2	11
3	12
4	13
1	10
2	11
3	12
4	13
1	10
2	11
3	12
4	13
1	10
2	11
3	12

Index	Value
4	13
1	10
2	11
3	12
4	13
1	10
2	11
3	12
4	13
1	10
2	11
3	12
4	13
1	10
2	11
3	12
4	13
1	10
2	11
3	12
4	13

Tabulka 1: A looong table

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## 3.2 Subheading Level 2

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Shape	Area
Circle	$\pi r^2$

Shape	Area
Square	$a^2$
Rectangle	$ab$

Tabulka 2: A simple table

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Definujeme:

$$\phi := \frac{1 + \sqrt{5}}{2} \quad (1)$$

Pomocí rovnice 1, dostaneme:

$$F_n = \left\lfloor \frac{1}{\sqrt{5}} \phi^n \right\rfloor$$

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$$E = \sqrt{m_0^2 + p^2} \\ \approx 125 \text{ GeV}$$

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$$E = mc^2 \quad (2.1)$$

$$= \sqrt{p^2 c^2 + m^2 c^4} \quad (2.2)$$

### 3.3 Subheading Level 2

Skalární součin dvou vektorů  $\vec{a}$  a  $\vec{b}$  je znázorněn rovnicí 3.

$$\begin{aligned} \langle a, b \rangle &= \vec{a} \cdot \vec{b} \\ &= a_1 b_1 + a_2 b_2 + \dots a_n b_n \\ &= \sum_{i=1}^n a_i b_i. \end{aligned} \quad (3.1)$$

Notace sumy v rovnici 3.1 je užitečný způsob zápisu skalárního součinu dvou vektorů.

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## Kapitola 4

# Heading Level 1

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## 4.1 Heading Level 2

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### 4.1.1 Heading Level 2

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## 4.2 Heading Level 3

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## Kapitola 5

# Heading 5

Jelikož základ nehomogenní funkce je roven jedné, počet výskytů (násobnost) tohoto základu v multimnožině kořenu charakteristické rovnice je roven jedné a největší exponent  $n$ -ka nehomogenní funkce je taktéž roven jedné, je tvar obecného partikulárního řešení rekurentní rovnice  $p_n$  roven:

$$\begin{aligned} p_n^{(p)} &= n^1(\beta_1 n^1 + \beta_0)1^n = n(\beta_1 n + \beta_0) = \beta_1 n^2 + \beta_0 n \\ p_n^{(p)} &= \varphi n^2 + \gamma n \quad (\gamma = \beta_0, \varphi = \beta_1). \end{aligned}$$

Neznámé  $\gamma$  a  $\varphi$  nalezneme substitucí členů  $p_n$  v původní rekurentní rovnici:

$$p_n = 3p_{n-1} - 2p_{n-2} - 10n.$$

partikulárním řešením  $p_n^{(p)}$  a vyřešíme soustavu dvou rovnic (dvě kvůli dvěma neznámým), kde si za  $n$  zvolíme jakékoliv čísla z  $\mathbb{N}_0$ .

$$p_n \leftarrow p_n^{(p)}:$$

$$p_n^{(p)} = 3p_{n-1}^{(p)} - 2p_{n-2}^{(p)} - 10n$$

$$\begin{aligned} \varphi n^2 + \gamma n &= 3(\varphi(n-1)^2 + \gamma(n-1)) \\ &\quad - 2(\varphi(n-2)^2 + \gamma(n-2)) - 10n \end{aligned}$$

$$\begin{aligned} \varphi n^2 + \gamma n &= 3(\varphi(n^2 - 2n + 1) + \gamma n - \gamma) \\ &\quad - 2(\varphi(n^2 - 4n + 4) + \gamma n - 2\gamma) - 10n \end{aligned}$$

$$\begin{aligned} \varphi n^2 + \gamma n &= 3(\varphi n^2 - 2\varphi n + \varphi + \gamma n - \gamma) \\ &\quad - 2(\varphi n^2 - 4\varphi n + 4\varphi + \gamma n - 2\gamma) - 10n \end{aligned}$$

$$\begin{aligned} \varphi n^2 + \gamma n &= 3\varphi n^2 - 6\varphi n + 3\varphi + 3\gamma n - 3\gamma \\ &\quad - 2\varphi n^2 + 8\varphi n - 8\varphi - 2\gamma n + 4\gamma - 10n \end{aligned}$$

$$\begin{aligned} \varphi n^2 + \gamma n &= \varphi n^2 + 2\varphi n - 5\varphi + \gamma n + \gamma - 10n \\ 0 &= 2\varphi n - 5\varphi + \gamma - 10n \end{aligned}$$

Nyní si za  $n$  zvolíme například nulu a jedničku.

$$n = 0: \quad 0 = 2\varphi \cdot 0 - 5\varphi + \gamma - 10 \cdot 0$$

$$n = 1: \quad 0 = 2\varphi \cdot 1 - 5\varphi + \gamma - 10 \cdot 1$$

$$\begin{cases} 0 = -5\varphi + \gamma \\ 0 = 2\varphi - 5\varphi + \gamma - 10 \end{cases}$$

$$\begin{cases} 0 = \gamma - 5\varphi \\ 10 = \gamma - 3\varphi \end{cases}$$

$$\left(\begin{array}{cc|c} 1 & -5 & 0 \\ 1 & -3 & 10 \end{array}\right) \xrightarrow[R_2 \leftarrow R_2 - R_1]{\sim} \left(\begin{array}{cc|c} 1 & -5 & 0 \\ 0 & 2 & 10 \end{array}\right) \xrightarrow[R_2 \leftarrow \frac{1}{2}R_2]{\sim} \left(\begin{array}{cc|c} 1 & -5 & 0 \\ 0 & 1 & 5 \end{array}\right)$$

$$\varphi = 5$$

$$\gamma - 5 \cdot \varphi = 0 \Leftrightarrow \gamma = 25$$

Tudíž řešení partikulární rovnice  $p_n^{(p)}$  je:

$$p_n^{(p)} = \varphi n^2 + \gamma n$$

$$\underline{p_n^{(p)} = 5n^2 + 25n.}$$



# Závěr

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detraxisse, ut aliquam ex eo est consecutus? – Laudem et caritatem, quae sunt vitae sine metu degendae praesidia firmissima. – Filium morte multavit. – Si sine causa, nollem me ab eo delectari, quod ista Platonis, Aristoteli, Theophrasti orationis ornamenta neglexerit. Nam illud quidem physici, credere aliquid esse minimum, quod profecto numquam putavisset, si a Polyaeo, familiari suo, geometrica discere maluisset quam illum etiam ipsum dedocere. Sol Democrito magnus videtur, quippe homini erudito in geometriaque perfecto, huic pedalis fortasse; tantum enim esse omnino in nostris poetis aut inertissimae segnitiae est aut fastidii delicatissimi. Mihi quidem videtur, inermis ac nudus est. Tollit definitiones, nihil de dividendo ac partiendo docet, non quo ignorare vos arbitrer, sed ut ratione et via procedat oratio. Quaerimus igitur, quid sit extremum et ultimum bonorum, quod omnium philosophorum sententia tale debet esse.

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## A Qsort implementation

Implementation is in Haskell.

```
1 quicksort [] = []
2 quicksort (p:xs) = (quicksort lesser) ++ [p] ++ (quicksort greater)
3   where
4     lesser = filter (< p) xs
5     greater = filter (>= p) xs
```

Yes. Very cool.

### Algorithm 1: Binary Search

```
1: procedure BINARY-SEARCH( $A, n, v$ )
2:   ▷ Initialize the search range
3:    $l \leftarrow 1$ 
4:    $r \leftarrow n$ 
5:
6:   while  $l \leq r$  do
7:      $mid \leftarrow \text{floor}(\frac{l+r}{2})$ 
8:     if  $A[mid] < v$  then
9:        $l \leftarrow m + 1$ 
10:    else if  $A[mid] > v$  then
11:       $r \leftarrow m - 1$ 
12:    else
13:      return  $m$ 
14:    end
15:  end
16:  return null
17: end
```

---

## B Shit table

A	B
B	C
C	D

---

### Algorithm 2: Variable Assignment

---

1:  $x \leftarrow y$

---

## C OpenGL Shader Compilation

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---

```

1  unsigned int OpenGLShader::Compile(
2      const std::unordered_map<unsigned int, std::string>& sources
3  ) const
4  {
5      EG_PROFILE_FUNCTION();
6
7      EG_CORE_ASSERT(sources.size() >= 0 && sources.size() <= 3,
8          "Can only have three shader sources \
9          (vertex, geometry, fragment)!");
10
11     unsigned int program;
12     EG_OPENGL_CALL(program = glCreateProgram());
13
14     std::vector<unsigned int> shaders(sources.size());
15     for (const auto& [type, source] : sources)
16     {
17         auto shader = CompileSource(type, source);
18         shaders.push_back(shader);
19         EG_OPENGL_CALL(glAttachShader(program, shader));
20     }
21
22     EG_OPENGL_CALL(glLinkProgram(program));
23
24     int status;
25     EG_OPENGL_CALL(glGetProgramiv(program, GL_LINK_STATUS, &status));
26     if (status == GL_FALSE)
27     {
28         int length;
29         EG_OPENGL_CALL(glGetProgramiv(
30             program, GL_INFO_LOG_LENGTH, &length));
31
32         std::vector<char> message(length);
33         EG_OPENGL_CALL(glGetProgramInfoLog(
34             m_RendererID, length, &length, message.data()));
35
36         EG_OPENGL_CALL(glDeleteShader(program));
37         for (auto shader : shaders)
38         {
39             EG_OPENGL_CALL(glDeleteShader(shader));
40         }
41         EG_CORE_ERROR("{} ", message.data());
42         EG_CORE_ASSERT(false, "Shader compilation failed!");
43         return 0;
44     }
45
46     EG_OPENGL_CALL(glValidateProgram(program));
47     for (auto shader : shaders)
48     {
49         EG_OPENGL_CALL(glDeleteShader(shader));
50     }
51
52     return program;
53 }
```

---

Výpis 3: C++ method for GLSL shader compilation



## D C# code

---

```

1  using System.Diagnostics;
2  using System.Security.Claims;
3  using CoworkingApp.Models;
4  using CoworkingApp.Models.Misc;
5  using CoworkingApp.Models.ViewModels;
6  using CoworkingApp.Services.Repositories;
7  using Microsoft.AspNetCore.Authorization;
8  using Microsoft.AspNetCore.Mvc;
9
10 namespace CoworkingApp.Controllers.ViewControllers;
11
12 public class HomeController
13 {
14     IWorkspaceRepository workspaceRepository,
15     ICoworkingCenterRepository coworkingCenterRepository,
16     IReservationRepository reservationRepository,
17     IUserRepository userRepository
18 }
19 : Controller
20 {
21     [HttpGet]
22     public async Task<IActionResult> Index()
23     {
24         var workspaces = await workspaceRepository.GetWorkspaces(new ()
25         {
26             HasPricing = true,
27             IncludePricings = true,
28             IncludeStatus = true,
29         });
30
31         var coworkingCenters = await coworkingCenterRepository.GetCenters(
32             new CoworkingCenterFilter());
33
34         return View(new HomeIndexViewModel()
35         {
36             Workspaces = workspaces,
37             CoworkingCenters = coworkingCenters
38         });
39     }
40
41     [HttpGet]
42     [Authorize]
43     public async Task<IActionResult> Dashboard(
44         [FromQuery] ReservationSort reservationSort = ReservationSort.None)
45     {
46         var userId = User.GetUserId();
47
48         if (userId == null)
49         {
50             return Unauthorized(new { message = "User not found" });
51         }
52
53         var reservations = await reservationRepository
54             .GetReservations(new ReservationsFilter
55             {
56                 CustomerId = userId,
57                 IsCancelled = false,
58                 IncludeWorkspace = true,
59                 Sort = reservationSort,
60             });
61
62         var user = (await userRepository.GetUsers(new UserFilter
63         {
64             UserId = userId

```

---

---

```
65         })).Single();
66
67         return View(new HomeDashboardViewModel
68         {
69             User = user,
70             Reservations = reservations,
71             ReservationSort = reservationSort,
72         });
73     }
74
75     [HttpGet]
76     public async Task<IActionResult> Privacy()
77     {
78         return View();
79     }
80
81     [ResponseCache(
82         Duration = 0,
83         Location = ResponseCacheLocation.None, NoStore = true)]
84     public IActionResult Error()
85     {
86         return View(new ErrorViewModel
87         {
88             RequestId = Activity.Current?.Id ?? HttpContext.TraceIdentifier
89         });
90     }
91 }
```

---

Výpis 4: Computer program in C# language