Odločitveni sistemi - 1. seminarska - Odločitveni model

Tema: Izbira nove grafične kartice

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Kazalo

Uvod

Za problem izbire grafične kartice sem se odločil, ker se že nekaj časa soočam z dejstvom da moram kmalu nadgraditi svoj računalnik in se mi zdi, da je grafična kartica ena izmed najpomembnejših (in verjetno najdražjih) komponent. Prav zaradi tega dejstva sem izbral to tematiko, saj menim, da mi lahko olajša težko izbiro.

Podatki

V izboru imam na začetku 50 najpopularnejših grafičnih kartic v zadnjih letih, podatke o katerih sem pridobil iz spletne strani techpowerup.com (na voljo na povezavi: https://www.techpowerup.com/gpu-specs/). Tem podatkom sem dodal še ceno v dolarjih, katero sem pridobil iz spletne strani newegg.com (na voljo na povezavi: https://www.newegg.com/), in razdelil podatke o Senčilnikih, TMU ter ROP na 3 različne kriterije. Ker bom nadgrajeval celotni računalnik, sem se odločil, da izbire ne bom omejeval glede na povezljivost z matično ploščo, saj bo le ta izbrana po izbiri grafične kartice, in ne obratno. Te podatke bom tekom seminarske tudi prilagajal (npr. znebil se kartic katerih cena ni poznana, kartic, ki še niso izšle ipd.).

Hierarhično drevo

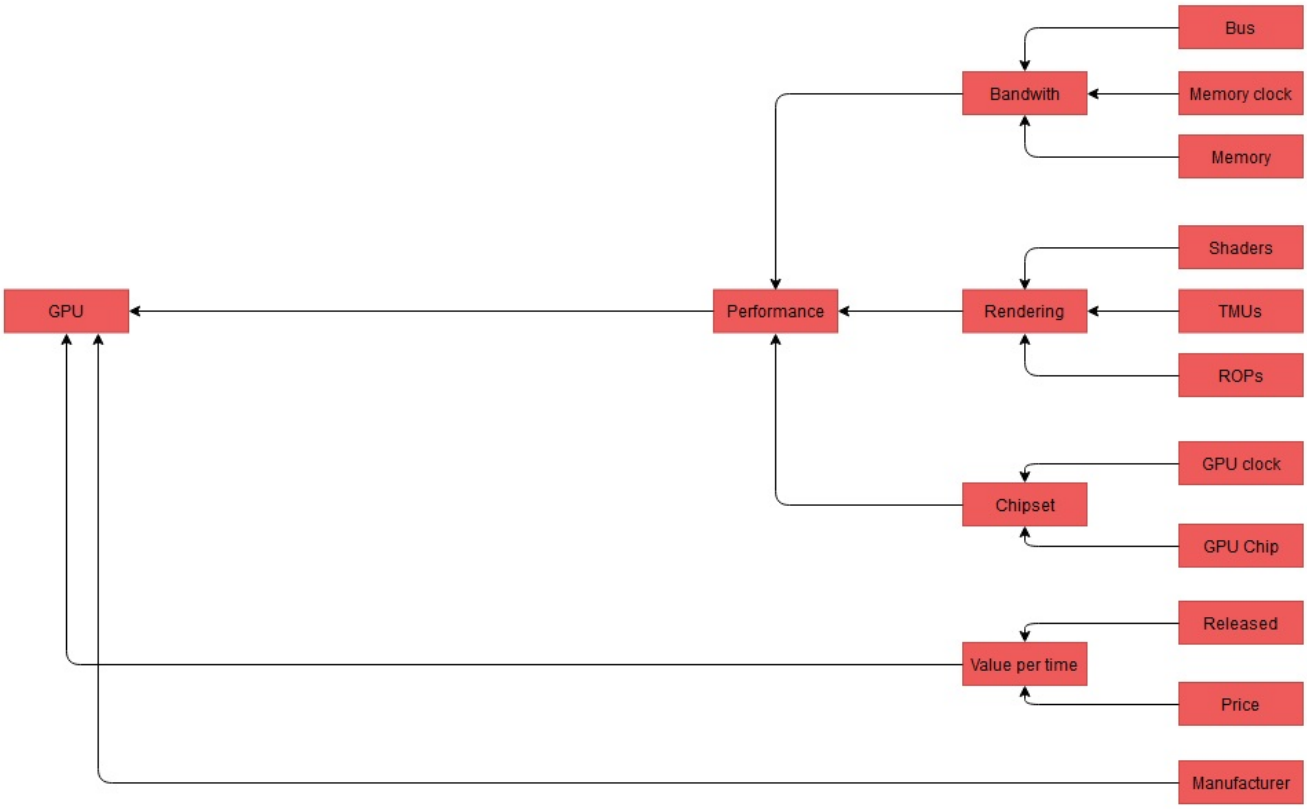
Hierarhično drevo je sestavljeno iz 11 kriterijev ter 5 izpeljanih vozlišč.

- Kriteriji Bus, Memory in Memory clock so združeni v vozlišče Bandwith, ki predstavlja mero prenosa podatkov v spominu.
- Kriteriji Shaders, TMUs, ROPs so združeni v vozlišče Rendering, ki predstavlja zmožnost uprizoritve grafične kartice.
- Kriterija GPU clock in GPU chip sta združena v vozlišče Chipset, ki predstavlja zmogljivost glavnega čipa grafične kartice.
- Vozlišča Bandwith, Rendering in Chipset so združena v vozlišče Performance, ki predstavlja celotno zmogljivost.
- Kriterija Release in Price sta združena v vozlišče Value per time, ki predstavlja vrednost kartice glede na čas.
- Vozlišči Performance in Value per time ter kriterij Manufacturer so združeni v vozlišče GPU, ki predstavlja celotno grafično kartico.

In [165…

```
from IPython.display import Image
Image(filename='resources/hierarchy tree.png')
```

Out[165]:



Priprava podatkov

In [166…

```
import numpy as np
import pandas as pd
import datetime
import matplotlib as mp
from matplotlib import pyplot as plt

data = pd.read_csv('data.csv', encoding='utf-8', sep=';')

# Remove GPUs with unknown price.
data = data[pd.notna(data.Price)]

# Remove unreleased GPUs. This means removing records with
# only the year as their release date.
data = data[data.Released.apply(lambda x : len(x) != 4)]
```

Pregled podatkov

Spodaj je prikazanih prvih 5 vrstic popravljenega podatkovnega okvirja.

In [167…

```
data.head(5)
```

Out[167]:

	Product Name	GPU Chip	Released	Bus	Memory	GPU clock	Memory clock	Shaders	TMUs	ROPs	Price	Manufacturer
0	GeForce RTX 4090	AD102	September 20, 2022	PCIe 4.0 x16	24 GB, GDDR6X, 384 bit	2235 MHz	1313 MHz	16384	512	176	2699.00	NVIDIA
3	GeForce RTX 3060	GA106	January 12, 2021	PCIe 4.0 x16	12 GB, GDDR6, 192 bit	1320 MHz	1875 MHz	3584	112	48	369.39	NVIDIA
4	GeForce RTX 3060 Ti	GA104	December 1, 2020	PCIe 4.0 x16	8 GB, GDDR6, 256 bit	1410 MHz	1750 MHz	4864	152	80	449.99	NVIDIA
5	GeForce RTX 3070	GA104	September 1, 2020	PCIe 4.0 x16	8 GB, GDDR6, 256 bit	1500 MHz	1750 MHz	5888	184	96	549.99	NVIDIA
6	Radeon RX 580	Polaris 20	April 18, 2017	PCIe 3.0 x16	8 GB, GDDR5, 256 bit	1257 MHz	2000 MHz	2304	144	32	402.26	AMD

Spodaj so prikazani kriteriji, glede na katere bo model izbiral.

In [168…

```
count = 0
for criteria in data.columns:
    if criteria != 'Product Name':
        if count < len(data.columns) - 1:
            print(criteria, end=', ')
        elif count == len(data.columns) - 1:
            print(criteria, end='')
    count += 1
```

```
GPU Chip, Released, Bus, Memory, GPU clock, Memory clock, Shaders, TMUs, ROPs, Price, Manufacturer
```

Spodaj je prikazanih 10 variant, oziroma grafičnih kartic, ki so v izboru.

In [169…
```
count = 0
for variant in data['Product Name']:
    if count < 9:
        print(variant, end=', ')
    elif count == 9:
        print(variant, end='')
    count += 1
```

```
GeForce RTX 4090, GeForce RTX 3060, GeForce RTX 3060 Ti, GeForce RTX 3070, Radeon RX 580, GeForce RTX 2060, GeF
orce RTX 3080, Radeon RX 6600, Radeon RX 6700 XT, Radeon RX 6600 XT
```

Uteži in funkcije koristnosti

Funkcije koristnosti

Spodaj so prikazane funkcije, ki pretvorijo vrednosti kriterijev v koristnosti, kar pomeni, da pretvorijo vse kriterije na isti razpon med 0 in 100. To storim tako, da zvezne kriterije normaliziram na skalo 0 = najslabše, 100 = najboljše. Pri diskretnih vrednostih pa sem vrednosti razdelil na enakomerne intervale med 0 in 100.
Pri kriteriju GPU Chip sem podatke, ki so mi pomagali pri razvrščanju čipov, pridobil iz spletne strani technical city (dostopna na: https://technical.city/en/video)

In [170…
```
# First set or calculate appropriate max and min values for certain ranges.
# This is done to increase performance, because the values do not have to be
# calculated on each function call.
new_scale_min_r = 100
new_scale_max_r = 0

new_scale_min = 0
new_scale_max = 100

max_memory_gb = max([int(i.split(',')[0][:2].replace(' ', '')) for i in data['Memory']])
min_memory_gb = min([int(i.split(',')[0][:2].replace(' ', '')) for i in data['Memory']])

max_memory_bits = max([int(i.split(',')[2][:4].replace(' ', '')) for i in data['Memory']])
min_memory_bits = min([int(i.split(',')[2][:4].replace(' ', '')) for i in data['Memory']])

max_bus_version = max([float(i.split(' ')[1]) for i in data['Bus']])
min_bus_version = min([float(i.split(' ')[1]) for i in data['Bus']])

max_bus_channels = max([int(i.split(' ')[2][-2:].replace('x', '')) for i in data['Bus']])
min_bus_channels = min([int(i.split(' ')[2][-2:].replace('x', '')) for i in data['Bus']])

max_release_date = max([datetime.datetime.strptime(i, "%B %d, %Y").date() for i in data['Released']])
min_release_date = min([datetime.datetime.strptime(i, "%B %d, %Y").date() for i in data['Released']])

def normalize_price(val : float) -> float:
    """
    Normalizes the GPU price on a scale of \n
    100 to 0.

    :param val: The price of the GPU.
    """
    if val == min(data.Price):
        return 100
    if val == max(data.Price):
        return 0
    return ((val - min(data.Price)) * (new_scale_max_r - new_scale_min_r)) \
        / (max(data.Price) - min(data.Price)) + new_scale_min_r


def normalize_GPU_clock(val : str) -> float:
    """
    Normalizes the GPU clock on a scale of \n
    0 to 100.

    :param val: The GPU clock speed.
    """
    numeric_clocks = pd.to_numeric(data['GPU clock'].str[:4], errors='coerce').tolist()
    val = int(val[:4])
    if val == min(numeric_clocks):
        return 0
    if val == max(numeric_clocks):
        return 100
    return ((val - min(numeric_clocks)) * (new_scale_max - new_scale_min)) \
        / (max(numeric_clocks) - min(numeric_clocks)) + new_scale_min


def normalize_memory_clock(val : str) -> float:
    """
    Normalizes the memory clock on a scale of \n
    0 to 100.
```

```
    :param val: The memory clock speed.
    """
    numeric_clocks = pd.to_numeric(data['Memory clock'].str[:4], errors='coerce').tolist()
    val = int(val[:4])
    if val == min(numeric_clocks):
        return 0
    if val == max(numeric_clocks):
        return 100
    return ((val - min(numeric_clocks)) * (new_scale_max - new_scale_min)) \
        / (max(numeric_clocks) - min(numeric_clocks)) + new_scale_min


def normalize_shaders(val : float) -> float:
    """
    Normalizes the shaders on a scale of \n
    0 to 100.

    :param val: The shaders.
    """
    if val == min(data['Shaders']):
        return 0
    if val == max(data['Shaders']):
        return 100
    return ((val - min(data['Shaders'])) * (new_scale_max - new_scale_min)) \
        / (max(data['Shaders']) - min(data['Shaders'])) + new_scale_min


def normalize_TMUs(val : float) -> float:
    """
    Normalizes the TMUs on a scale of \n
    0 to 100.

    :param val: The TMUs.
    """
    if val == min(data['TMUs']):
        return 0
    if val == max(data['TMUs']):
        return 100
    return ((val - min(data['TMUs'])) * (new_scale_max - new_scale_min)) \
        / (max(data['TMUs']) - min(data['TMUs'])) + new_scale_min


def normalize_ROPs(val : float) -> float:
    """
    Normalizes the ROPs on a scale of \n
    0 to 100.

    :param val: The ROPs.
    """
    if val == min(data['ROPs']):
        return 0
    if val == max(data['ROPs']):
        return 100
    return ((val - min(data['ROPs'])) * (new_scale_max - new_scale_min)) \
        / (max(data['ROPs']) - min(data['ROPs'])) + new_scale_min


def normalize_manufacturer(val : str) -> float:
    """
    Normalizes the ROPs on a scale of \n
    0 to 100.

    :param val: The ROPs.
    """
    if val == 'AMD':
        return 50
    if val == 'NVIDIA':
        return 100
    return 0


def normalize_memory(val : str) -> float:
    """
    Normalizes the memory string on a scale of \n
    0 to 100, by dividing it into 3 components: \n
    size, ram, and bits, linearly evaluating those \n
    components and averaging them.

    :param val: The memory value.
    """
    size = int(val.split(',')[0][:2])
    ram = val.split(',')[1][-2:].replace('R', '')
    bits = int(val.split(',')[2][:4].replace(' ', ''))

    ram_modifier = 0
    if ram == '6X':
        ram_modifier = 100
    elif ram == '6':
```

```
        ram_modifier = 66
    elif ram == '5X':
        ram_modifier = 33
    size_modifier = ((size - min_memory_gb) * (new_scale_max - new_scale_min)) \
        / (max_memory_gb - min_memory_gb) + new_scale_min
    bits_modifier = ((bits - min_memory_bits) * (new_scale_max - new_scale_min)) \
        / (max_memory_bits - min_memory_bits) + new_scale_min

    return (ram_modifier + size_modifier + bits_modifier) / 3


def normalize_bus(val : str) -> float:
    """
    Normalizes the bus string on a scale of \n
    0 to 100, by dividing it into 2 components: \n
    version and channels, linearly evaluating those \n
    components and averaging them.

    :param val: The bus value.
    """
    bus_version = float(val.split(' ')[1])
    bus_channels = int(val.split(' ')[2][-2:].replace('x', ''))

    version_modifier = ((bus_version - min_bus_version) * (new_scale_max - new_scale_min)) \
        / (max_bus_version - min_bus_version) + new_scale_min
    channels_modifier = ((bus_channels - min_bus_channels) * (new_scale_max - new_scale_min)) \
        / (max_bus_channels - min_bus_channels) + new_scale_min

    return (version_modifier + channels_modifier) / 2


def normalize_released(val : str) -> float:
    """
    Normalizes the date string on a scale of \n
    0 to 100.

    :param val: The date value.
    """

    return ((datetime.datetime.strptime(val, "%B %d, %Y").date() - min_release_date).days \
        * (new_scale_max - new_scale_min)) / (max_release_date - min_release_date).days + new_scale_min


def normalize_GPU_chip(val : str) -> float:
    """
    Normalizes the GPU chip string on a scale of \n
    0 to 100, by splitting it into chip name and \n
    version, linearizing them both, and scaling them \n
    due to different importance (i.e. worst GP chip \n
    is better than best GA chip).

    :param val: The GPU chip value.
    """
    chip_name = val[0:[i.isdigit() for i in val].index(True)]
    # Lower is better.
    chip_version = int(val[[i.isdigit() for i in val].index(True):])
    # AD > GP > Navi > Polaris > GA > GM  > TU
    name_modifier = {
        'AD': 100,
        'GP':83.0,
        'Navi ': 66.4,
        'Polaris ': 49.8,
        'GA': 33.2,
        'GM': 16.6,
        'TU': 0
    }[chip_name]

    if chip_name == 'AD' or chip_name == 'Polaris ':
        version_modifier = 100
    else:
        max_chip_version = max([int(i[[k.isdigit() for k in i].index(True):]) for i in data['GPU Chip'] if \
            i[:[j.isdigit() for j in i].index(True)] == chip_name])
        min_chip_version = min([int(i[[k.isdigit() for k in i].index(True):]) for i in data['GPU Chip'] if \
            i[:[j.isdigit() for j in i].index(True)] == chip_name])
        version_modifier = ((chip_version - min_chip_version) * (new_scale_max_r - new_scale_min_r)) \
            / (max_chip_version - min_chip_version) + new_scale_min_r

    name_modifier *= 0.7
    version_modifier *= 0.3

    return name_modifier + version_modifier
```

In [171…

```
normalizations = {
    'Price': normalize_price,
    'Memory clock': normalize_memory_clock,
    'GPU clock': normalize_GPU_clock,
    'Memory': normalize_memory,
    'Bus': normalize_bus,
```

```
    'Shaders': normalize_shaders,
    'TMUs': normalize_TMUs,
    'ROPs': normalize_ROPs,
    'Released': normalize_released,
    'GPU Chip': normalize_GPU_chip,
    'Manufacturer': normalize_manufacturer
}
converted_data = data.copy()
for column in data.columns[1:]:
    converted_data[column] = data[column].apply(normalizations[column])

converted_data.head(10)
```

Out[171]:

	Product Name	GPU Chip	Released	Bus	Memory	GPU clock	Memory clock	Shaders	TMUs	ROPs	Price	Manufacturer
0	GeForce RTX 4090	100.000000	100.000000	100.000000	100.000000	93.389700	11.770245	100.0	100.000000	100.0	0.000000	100
3	GeForce RTX 3060	23.240000	80.357143	100.000000	50.484848	23.059185	64.689266	20.0	18.032787	20.0	89.772679	100
4	GeForce RTX 3060 Ti	38.240000	79.017857	100.000000	51.090909	29.976941	52.919021	28.0	26.229508	40.0	86.666718	100
5	GeForce RTX 3070	38.240000	76.116071	100.000000	51.090909	36.894696	52.919021	34.4	32.786885	50.0	82.813168	100
6	Radeon RX 580	64.860000	36.830357	50.000000	29.090909	18.216756	76.459510	12.0	24.590164	10.0	88.506017	50
7	GeForce RTX 2060	22.000000	56.887755	50.000000	41.393939	26.518063	52.919021	9.6	19.672131	20.0	94.797323	100
8	GeForce RTX 3080	53.240000	76.116071	100.000000	72.121212	32.282859	0.000000	52.0	50.819672	50.0	67.784325	100
9	Radeon RX 6600	46.480000	89.094388	66.666667	37.757576	46.579554	52.919021	8.8	18.032787	30.0	94.759172	50
10	Radeon RX 6700 XT	48.787692	81.951531	100.000000	50.484848	100.000000	76.459510	13.6	27.868852	30.0	86.281363	50
11	Radeon RX 6600 XT	46.480000	86.702806	66.666667	37.757576	72.867025	76.459510	10.4	21.311475	30.0	90.134913	50

Uteži

Prej naštete kriterije in izpeljana vozlišča sem nato utežil z vrednostmi med 0 in 1 glede na svoje preference oziroma mnenja, kaj pri grafični kartici mi je pomembno in kaj ne. To sem storil tako, da sem vsakemu kriteriju ročno določil vrednosti od spodaj navzgor (od listov do korena drevesa). Te vrednosti se morajo znotraj istega nivoja sešteti v 1, prav tako se morajo vse dejanske uteži na koncu sešteti v 1.

In [172…

```
# First level

# Bandwith
bus_weight = 0.3
memory_clock_weight = 0.30
memory_weight = 0.40

# Rendering
shaders_weight = 0.30
TMUs_weight = 0.40
ROPs_weight = 0.30

# Chipset
GPU_clock_weight = 0.50
GPU_chip_weight = 0.50

# Value per time
released_weight = 0.20
price_weight = 0.80

# Second level

# Performance
bandwith_weight = 0.30
rendering_weight = 0.20
chipset_weight = 0.50

# Third level
```

```
performance_weight = 0.40
value_per_time_weight = 0.40
manufacturer_weight = 0.20

actual_weights = {
    'Bus': performance_weight * bandwith_weight * bus_weight,
    'Memory clock': performance_weight * bandwith_weight * memory_clock_weight,
    'Memory': performance_weight * bandwith_weight * memory_weight,
    'Shaders': performance_weight * rendering_weight * shaders_weight,
    'TMUs': performance_weight * rendering_weight * TMUs_weight,
    'ROPs': performance_weight * rendering_weight * ROPs_weight,
    'GPU clock': performance_weight * chipset_weight * GPU_clock_weight,
    'GPU Chip': performance_weight * chipset_weight * GPU_chip_weight,
    'Released': value_per_time_weight * released_weight,
    'Price': value_per_time_weight * price_weight,
    'Manufacturer': manufacturer_weight
}

print('Actual weights: \n', {k:round(v, 3) for k, v in actual_weights.items()})
print('Do the values sum to 1: ', sum(actual_weights.values()) == 1.0)
```

```
Actual weights:
 {'Bus': 0.036, 'Memory clock': 0.036, 'Memory': 0.048, 'Shaders': 0.024, 'TMUs': 0.032, 'ROPs': 0.024, 'GPU cl
ock': 0.1, 'GPU Chip': 0.1, 'Released': 0.08, 'Price': 0.32, 'Manufacturer': 0.2}
Do the values sum to 1:  True
```

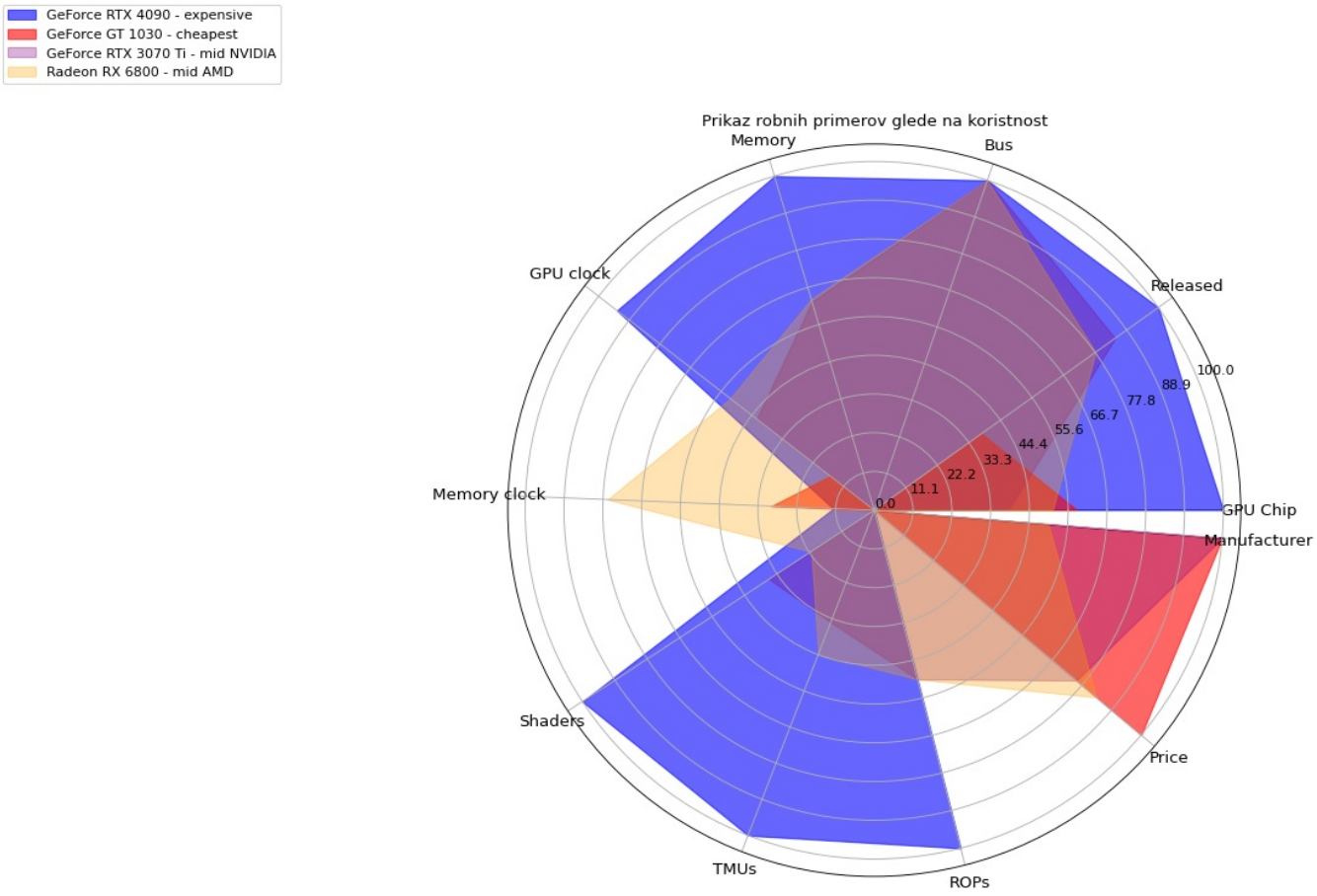
Pikazi kriterijev in uteži

Prikaz kriterijev

Sledi prikaz kriterijev štirih variant, najdražje, najcenejše in dveh približno povprečnih, ena AMD in ena NVIDIA.

In [173…

```
theta = np.linspace(0, 2 * np.pi - 0.08, len(converted_data.columns[1:]))
expensive = converted_data.loc[converted_data['Product Name'] == 'GeForce RTX 4090']
cheapest = converted_data.loc[converted_data['Product Name'] == 'GeForce GT 1030']
mid_nvidia = converted_data.loc[converted_data['Product Name'] == 'GeForce RTX 3070 Ti']
mid_amd = converted_data.loc[converted_data['Product Name'] == 'Radeon RX 6800']
ex, cp, mn, ma = dict(), dict(), dict(), dict()
for i in converted_data.columns[1:]:
    ex[i] = converted_data[converted_data['Product Name'] == 'GeForce RTX 4090'][i].to_list()[0]
    cp[i] = converted_data[converted_data['Product Name'] == 'GeForce GT 1030'][i].to_list()[0]
    mn[i] = converted_data[converted_data['Product Name'] == 'GeForce RTX 3070 Ti'][i].to_list()[0]
    ma[i] = converted_data[converted_data['Product Name'] == 'Radeon RX 6800'][i].to_list()[0]
fig=plt.figure(figsize=(12, 10), dpi= 80, facecolor='w', edgecolor='k')
ax = plt.subplot(111, projection='polar')
ax.fill_between(theta, np.array([v for v in ex.values()], dtype=float), 0, label='GeForce RTX 4090 - expensive'
ax.fill_between(theta, np.array([v for v in cp.values()], dtype=float), 0, label='GeForce GT 1030 - cheapest', 
ax.fill_between(theta, np.array([v for v in mn.values()], dtype=float), 0, label='GeForce RTX 3070 Ti - mid NVI
ax.fill_between(theta, np.array([v for v in ma.values()], dtype=float), 0, label='Radeon RX 6800 - mid AMD', al
ax.set_title("Prikaz robnih primerov glede na koristnost")
ax.set_xticks(theta)
ax.set_rticks(np.linspace(0, 100, 10))
ax.set_xticklabels(converted_data.columns[1:], size=12)
ax.legend(bbox_to_anchor=(-0.3, 1.2))
plt.show()
```

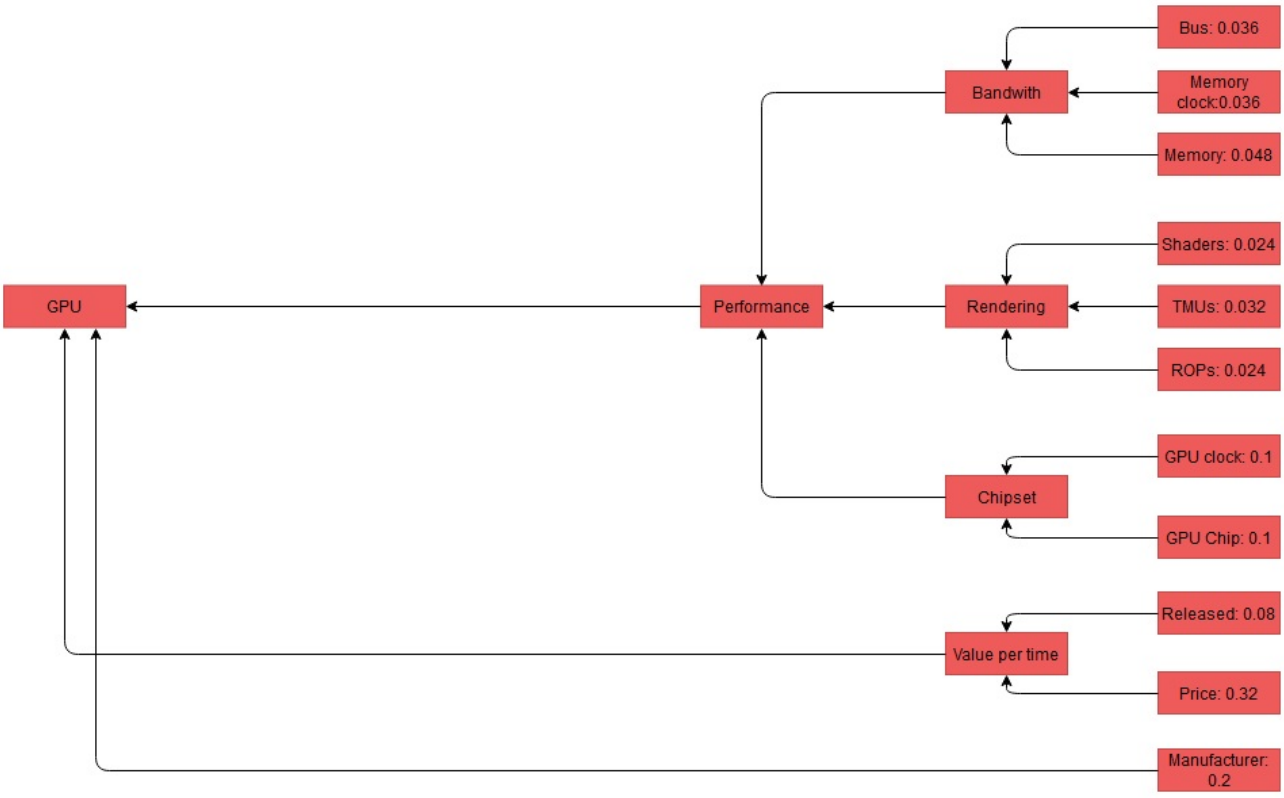


Prikaz uteži

Sledi prikaz hierarhičnega drevesa z uteženimi osnovnimi vozlišči, katerih vrednosti se seštejejo v ena kot je prikazano v poglavju Uteži in funkcije koristnosti - Uteži. Iz drevesa je razvidno, da ker sem študent, mi je najpomembnejša cena grafične kartice, nato karakteristike čipa grafične kartice, in nato karakteristike spomina. Prav tako ima visoko oceno proizvajalec, saj močno preferiram NVIDIA namesto AMD.

In [174…
```
Image(filename='resources/hierarchy tree - weighted.png')
```

Out[174]:



Ocene variant

Manjvredne variante

Sledi odstranjevanje manjvrednih variant, torej odstranjevanje variant, ki jih model ne bi izbral nikoli. To sem storil tako, da sem odstranil variante, ki so slabše v vsaj eni kategoriji od druge variante.

In [175…
```
def remove_inferior(data : pd.DataFrame):
    """
    Removes the inferior variants from dataset and returns
    the cleaned dataset and the variant names.

    :param data: The dataset.
    """
    rows, _ = data.shape
    inferior_variants = set()
    for row1 in range(rows):
        for row2 in range(row1 + 1, rows):
            delta_vector = data.iloc[row1, 1:] - data.iloc[row2, 1:]
            if all(i >= 0 for i in delta_vector):
                inferior_variants.add(data.index[row2])
            if all(i <= 0 for i in delta_vector):
                inferior_variants.add(data.index[row1])
    named_inferior_variants = set()
    for variant in inferior_variants:
        named_inferior_variants.add(data.iloc[variant, 0])
        data = data.iloc[data.index != variant, :]
    return data, named_inferior_variants

converted_data, inferirors = remove_inferior(converted_data)
print("Inferior variants: ", inferirors)
```

```
Inferior variants:  {'GeForce GTX 1660', 'Radeon RX 6800', 'Radeon RX 580 2048SP', 'Radeon RX 6950 XT'}
```

Ocene variant

Ko je bil podatkovni okvir očiščen, in odstranjene manjvredne variante, sem lahko začel z dejanskim ocenjevanjem variant. To sem storil tako, da sem definiral funkcijo, ki izračuna vrednost variante glede na njene koristnosti in uteži kriterijev. Nato sem to funkcijo pognal za vse variante, ki so ostale, in dobil urejen seznam variant.

In [176…
```
def score(variant : dict, weights : dict) -> float:
    """
    Evaluates the variant based on the weights.

    :param variant: The current variant.
    :param weights: The weights.
    """
    score = 0
    for k, v in variant.items():
        score += v * weights[k]
    return score

variant_scores = dict()
for variant_name in converted_data['Product Name']:
    variant_dict = dict()
    for column in converted_data[converted_data['Product Name'] == variant_name].columns[1:]:
        variant_dict[column] = \
            converted_data[converted_data['Product Name'] == variant_name][column].to_list()[0]
    variant_scores[variant_name] = round(score(variant_dict, actual_weights), 3)

for k, v in sorted(variant_scores.items(), key=lambda x:x[1], reverse=True):
    print(k, ': ', v, sep='')
```

```
GeForce GTX 1070: 71.616
GeForce GTX 1080 Ti: 71.539
GeForce RTX 3060 Ti: 71.305
GeForce RTX 3070: 71.135
GeForce RTX 3050 8 GB: 70.14
Radeon RX 6750 XT: 69.977
GeForce GTX 1080: 69.958
Radeon RX 6700 XT: 69.759
GeForce RTX 3060: 69.675
Radeon RX 6650 XT: 69.108
GeForce RTX 3070 Ti: 68.854
GeForce RTX 2060 SUPER: 68.658
GeForce GTX 1060 6 GB: 68.382
GeForce RTX 3090: 68.332
Radeon RX 5700 XT: 67.795
GeForce RTX 2070: 67.679
GeForce RTX 3080: 67.469
Radeon RX 6800 XT: 67.463
GeForce RTX 2080: 66.857
GeForce RTX 2060: 66.77
Radeon RX 6900 XT: 66.147
GeForce GTX 1660 SUPER: 66.036
Radeon RX 6800: 65.716
GeForce GTX 1050 Ti: 65.528
GeForce GTX 1660: 65.518
GeForce GTX 1650: 65.191
GeForce GTX 1660 Ti: 64.875
Radeon RX 6950 XT: 64.743
Radeon RX 6600: 64.382
GeForce RTX 2070 SUPER: 64.256
GeForce RTX 4090: 64.163
GeForce GT 1030: 63.494
Radeon RX 5500 XT: 62.156
GeForce RTX 2080 Ti: 62.151
GeForce RTX 3080 Ti: 60.723
GeForce GTX 960: 59.345
GeForce GTX 750 Ti: 58.826
Radeon RX 580: 56.84
GeForce RTX 3090 Ti: 55.781
```

Glede na moje uteži, opisane v prejšnih poglavjih, je razvidno, da so najboljše ocenjene variante starejše grafične kartice, katerim je cena že padla, a so svoje čase veljale za precej zmogljive. Zmagala je namreč grafična kartica NVIDIA GeForce GTX 1070. Zanimivo je, da je grafična kartica GeForce GTX 1080 TI bolje ocenjena kot GeForce 1080, čeprav je dražja. Najvrjetneje je to zato, ker je toliko bolj zmogljiva, da to prevesi višjo ceno. Prav tako je zanimivo, da so ene izmed najbolje ocenjenih grafičnih kartic tudi ene izmed dražji, kar je prav tako najvrjetneje zaradi toliko boljše zmogljivosti. Kljub temu pa so si prve tri variante po točkah precej blizu.

Na podlagi teh rezultatov sem si za alternativno varianto izbral Radeon RX 6600, saj je relativno povprečna AMD grafična kartica, ki pa so ocenjene slabše kot NVIDIA.

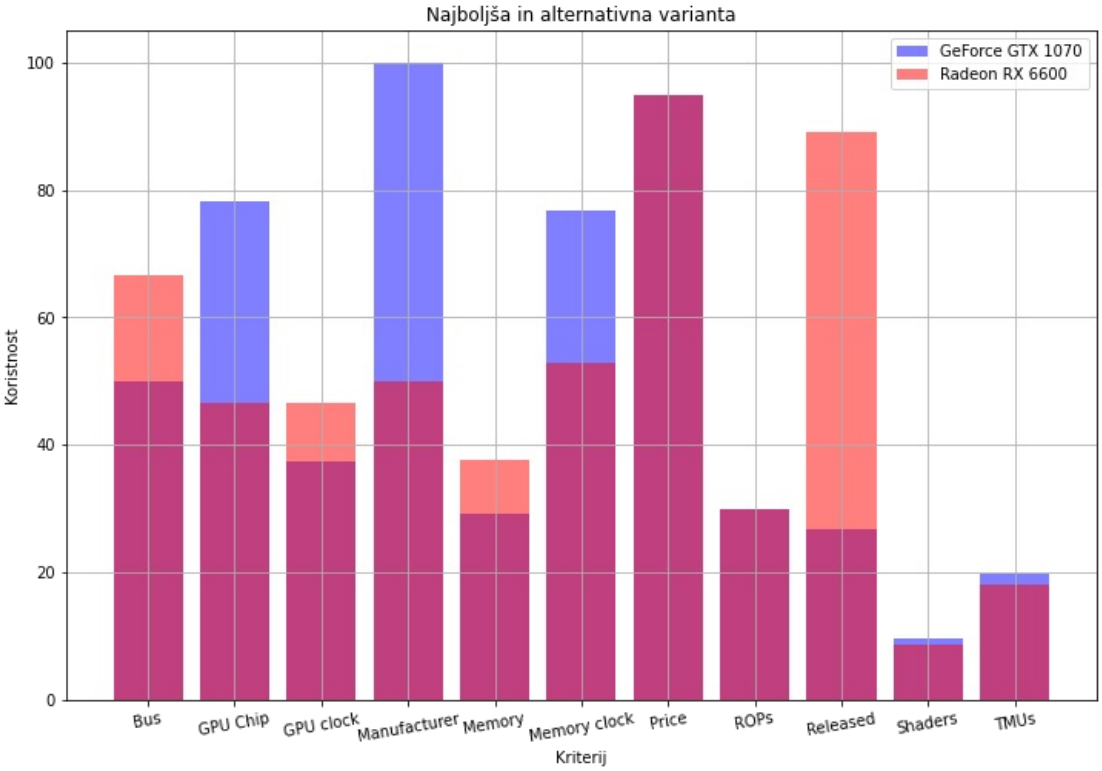
In [177…
```
print(converted_data[converted_data['Product Name'] == 'GeForce GTX 1070'].squeeze())
print(converted_data[converted_data['Product Name'] == 'Radeon RX 6600'].squeeze())
```

```
Product Name    GeForce GTX 1070
GPU Chip                   78.1
Released              26.881378
Bus                        50.0
Memory                29.090909
GPU clock              37.35588
Memory clock          76.647834
Shaders                      9.6
TMUs                  19.672131
ROPs                       30.0
Price                 94.951465
Manufacturer                100
Name: 35, dtype: object
Product Name    Radeon RX 6600
GPU Chip                 46.48
Released             89.094388
Bus                  66.666667
Memory               37.757576
GPU clock            46.579554
Memory clock         52.919021
Shaders                    8.8
TMUs                 18.032787
ROPs                      30.0
Price                94.759172
Manufacturer                50
Name: 9, dtype: object
```

Kot lahko vidimo, ima alternativna varianta dosti boljšo zmogljivost, ampak je dosti slabše ocenjena zaradi višje cene in drugega proizvajalca.

In [178…
```
top = converted_data.loc[converted_data['Product Name'] == 'GeForce GTX 1070']
alt = converted_data.loc[converted_data['Product Name'] == 'Radeon RX 6600']
```

```
top_dict = dict()
alt_dict = dict()

for column in converted_data.columns[1:]:
    top_dict[column] = top[column].to_list()[0]
    alt_dict[column] = alt[column].to_list()[0]

x1, y1 = zip(*(sorted(top_dict.items())))
x2, y2 = zip(*(sorted(alt_dict.items())))

fig, ax = plt.subplots(figsize=(12,8))
plt.grid()
plt.xticks(rotation=10)
ax.bar(x1, y1, label='GeForce GTX 1070', alpha=0.5, color='b')
ax.bar(x2, y2, label='Radeon RX 6600', alpha=0.5, color='r')
ax.set_title('Najboljša in alternativna varianta')
ax.set_xticks(x2)
ax.set_ylabel('Koristnost')
ax.set_xlabel('Kriterij')
ax.legend(loc=1)
plt.show()
```



Primerjava variant

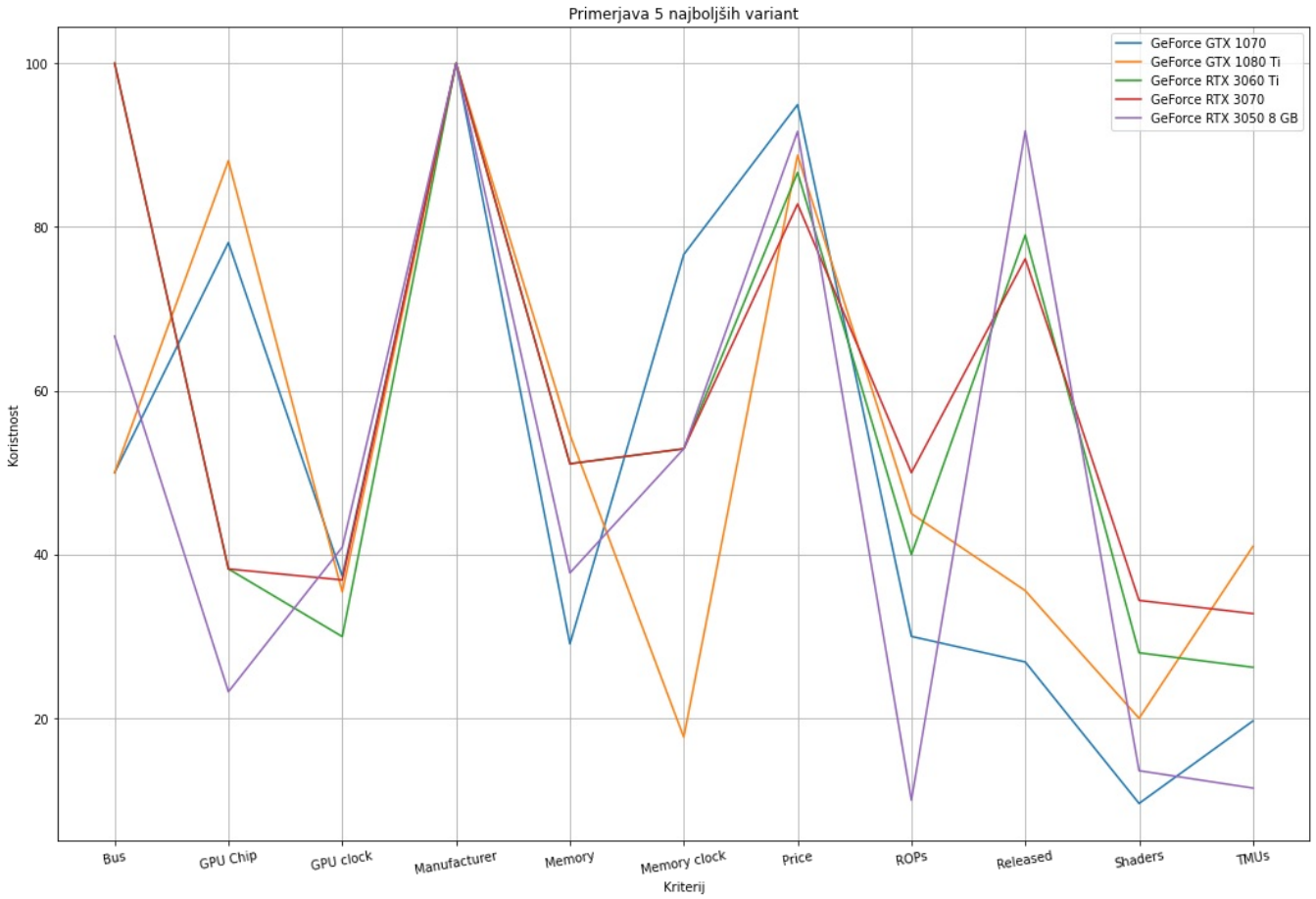
Primerjava variant z najboljšo

Z najboljšo varianto sem primerjal 5 najbolje ocenjenih in 5 najslabše ocenjenih, saj se mi zdi, da je ta prikaz najbolj zanimiv, prav tako pa ni smiselno da prikazujem primerjave za vse grafične kartice.

In [179…

```
variant_values = dict()

fig, ax = plt.subplots(figsize=(18,12))
plt.grid()
plt.xticks(rotation=10)

for column in converted_data.columns[1:]:
    top_dict[column] = top[column].to_list()[0]
    alt_dict[column] = alt[column].to_list()[0]

count = 0
for k, v in sorted(variant_scores.items(), key=lambda x:x[1], reverse=True):
    for column in converted_data.columns[1:]:
        variant_values[column] = converted_data[converted_data['Product Name'] == k][column]
    x, y = zip(*sorted(variant_values.items()))
    ax.plot(x, y, label=k)
    variant_values = dict()
    count += 1
    if count == 5:
        break

ax.set_title('Primerjava 5 najboljših variant')
ax.set_xticks(x2)
ax.set_ylabel('Koristnost')
ax.set_xlabel('Kriterij')
ax.legend(loc=1)
```

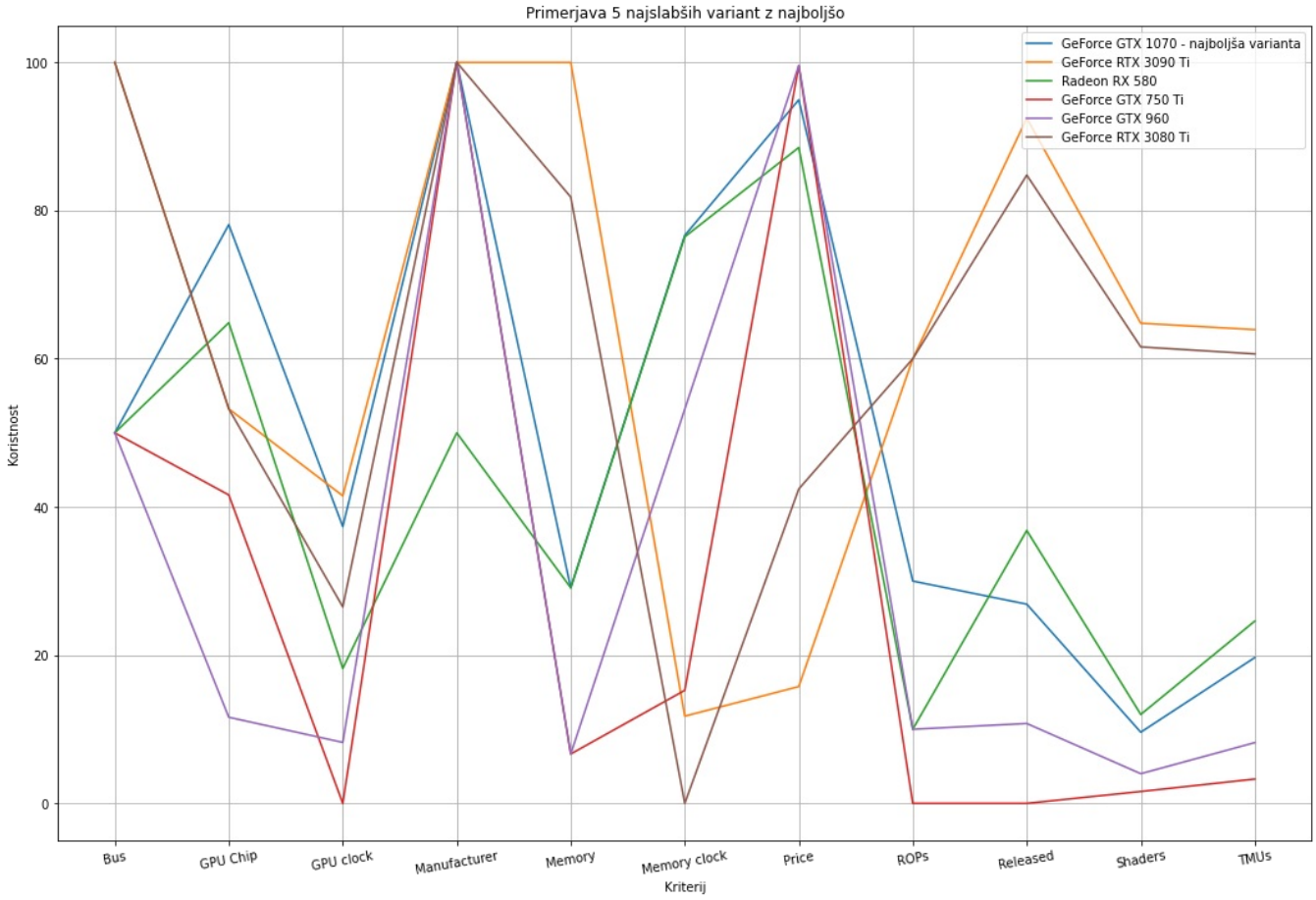
```
plt.show()
```



Kot lahko vidimo, imajo vse najboljše alternative zelo podobne koristnosti pri kriterijih Manufacturer, Price in Released.

In [180…

```
variant_values = dict()

fig, ax = plt.subplots(figsize=(18,12))
plt.grid()
plt.xticks(rotation=10)

for column in converted_data.columns[1:]:
    variant_values[column] = converted_data[converted_data['Product Name'] == 'GeForce GTX 1070'][column]
x, y = zip(*sorted(variant_values.items()))
ax.plot(x, y, label='GeForce GTX 1070 - najboljša varianta')

count = 0
variant_values = dict()
for k, v in sorted(variant_scores.items(), key=lambda x:x[1]):
    for column in converted_data.columns[1:]:
        variant_values[column] = converted_data[converted_data['Product Name'] == k][column]
    x, y = zip(*sorted(variant_values.items()))
    ax.plot(x, y, label=k)
    variant_values = dict()
    count += 1
    if count == 5:
        break

ax.set_title('Primerjava 5 najslabših variant z najboljšo')
ax.set_xticks(x2)
ax.set_ylabel('Koristnost')
ax.set_xlabel('Kriterij')
ax.legend(loc=1)
plt.show()
```



Pri pregledu primerjave najslabših variant z najboljšo lahko opazimo, da so najslabše variante ali najcenejše, in imajo zaradi tega zelo slabo performanco, ali pa so zelo drage, in zaradi tega kriterija dobijo nizko oceno.

Analiza

Map diagram

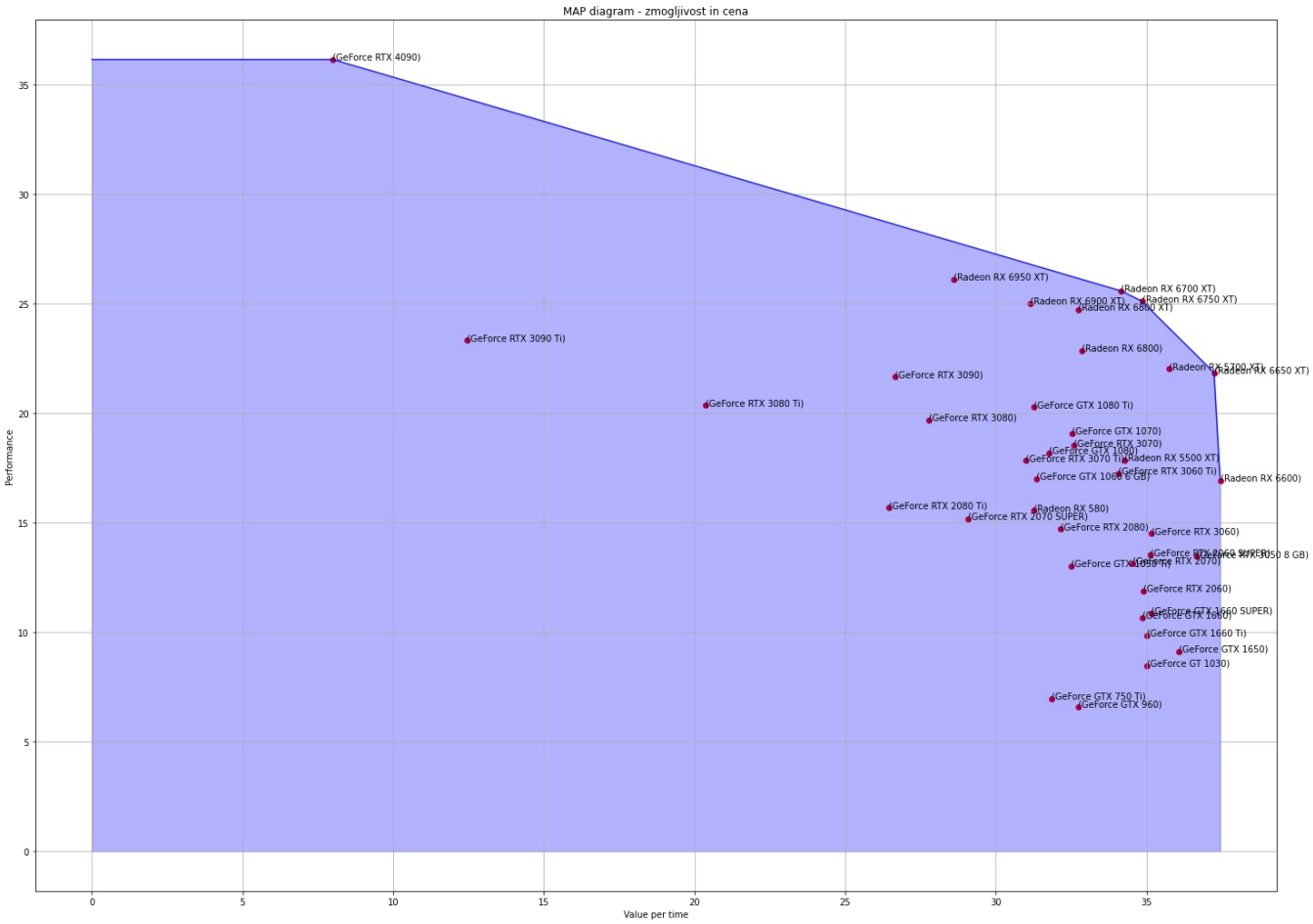
Map diagram nam vizualizira odločitvene modele na podalgi dveh izbranih kriterijev, ponavadi ga uporabljamo na izpeljanih kriterijih. Kriterija, ki sem ju izbral sta zmgoljivost (performance) in vrednost po času (value per time).

Map diagram sem naredil tako, da sem najprej prilagodil funkcijo za računanje ocene tako, da izračuna 2 ločeni oceni, eno za vsak izbran kriterij. Te oceni sem nato uporabil kot koordinate za "scatter plot", nato pa sem narisal še ovojnico.

In [181…

```
def map_score(variant : dict, weights : dict):
    """
    Calculates the map diagram score, which is the score based only
    on 2 criteria groups, in this case 'Value per time' and 'Performance'.

    :param variant: The current variant.
    :param weights: The weights.
    """
    score_ppv = 0
    score_performance = 0
    for k, v in variant.items():
        if k in ['Price', 'Released']:
            score_ppv += v * weights[k]
        elif k == 'Manufacturer':
            continue
        else:
            score_performance += v * weights[k]
    return score_ppv, score_performance

# Calculate the scores for performance and value per time.
map_scores = dict()
for variant_name in converted_data['Product Name']:
    variant_dict = dict()
    for column in converted_data[converted_data['Product Name'] == variant_name].columns[1:]:
        variant_dict[column] = \
            converted_data[converted_data['Product Name'] == variant_name][column].to_list()[0]
    map_scores[variant_name] = map_score(variant_dict, actual_weights)

prices = {k: v[0] for k, v in map_scores.items()}
performances = {k: v[1] for k, v in map_scores.items()}

fig, ax = plt.subplots(figsize=(25,18))
plt.grid()
```

```
# Display the values as scatter plot.
ax.scatter(prices.values(), performances.values(), color="red", s=35)
ax.set_xlabel('Value per time')
ax.set_ylabel('Performance')

line = []

# Annotate the data and get points of the enveloping line.
for name in sorted(prices.keys(), key=prices.get):
    if name == 'GeForce RTX 4090':
        line.append((0, performances[name]))
        line.append((prices[name], performances[name]))
    if name in ['Radeon RX 6700 XT', 'Radeon RX 6750 XT', 'Radeon RX 6650 XT', 'Radeon RX 6600']:
        line.append((prices[name], performances[name]))
    ax.annotate('(%s)'%name, xy=(prices[name], performances[name]), textcoords='data')

ax.plot([x for x, _ in line], [y for _, y in line], color='blue', alpha=0.8)
ax.fill_between([x for x, _ in line], [y for _, y in line], 0, color='blue', alpha=0.3)

ax.set_title('MAP diagram - zmogljivost in cena')

plt.show()
```



Kot lahko vidimo, ovojnico napenjajo variante:

- NVIDIA GeForce 4090
- AMD Radeon RX 6700 XT
- AMD Radeon RX 6750 XT
- AMD Radeon RX 6650 XT
- Radeon RX 6600

Prav tako lahko vidimo, da veliko variant ni smiselno izbrati v primerjavi z drugo varianto (imajo slabšo zmogljivost za isto vrednost po času):

- Veliko grafičnih kartic, ki ima koristnost Value per time 35, so po zmogljivosti slabše od Radeon RX 6750 XT
- GeForce GTX 2080 Ti, GeForce RTX 3080, GeForce RTX 3090 imajo slabšo zmogljivost za slabšo vrednost po času od Radeon RX 6950 XT

Do manjvrednih variant pride najvrjetneje zato, ker je vozlišče vrednost po času sestavljeno iz atributov cena in čas izdaje. Ko sem izločal manjvredne variante je lahko ena izmed teh variant imela boljšo ceno, a slabši čas izdaje kot druga varianta, in zato ni bila izločena.

Občutljivost modela

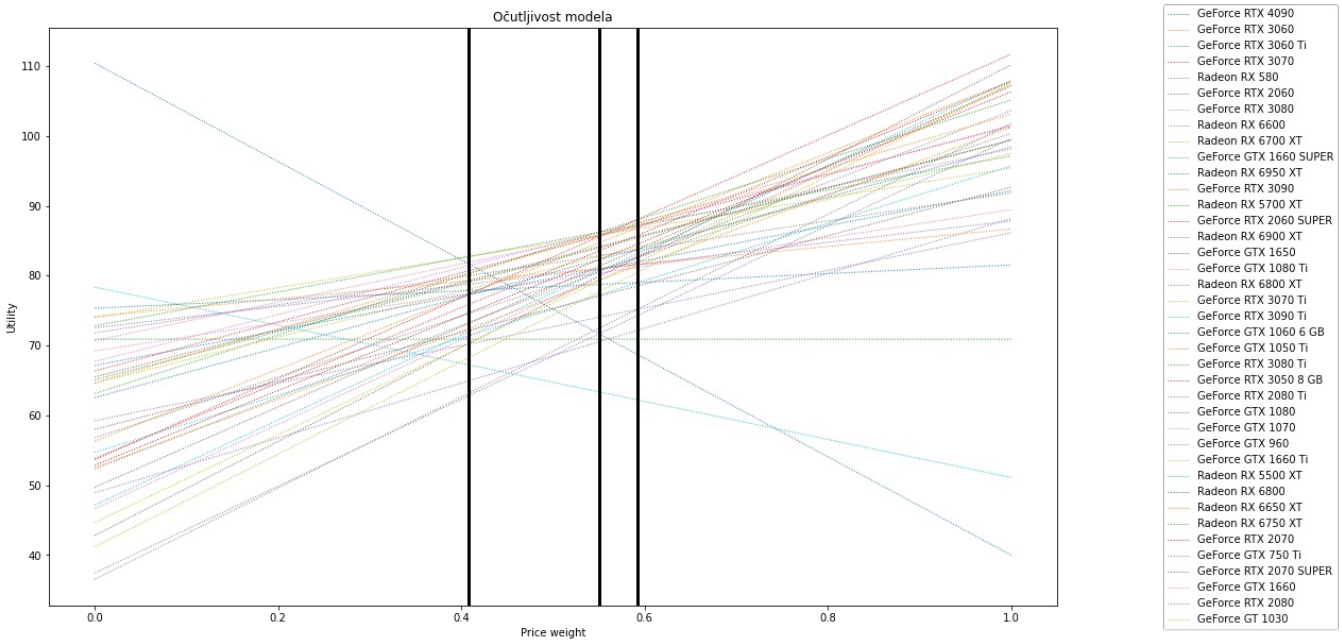
In [193]:
```
variable_vpt_weights = np.linspace(0, 1, 50)
```

```
variable_vpt_weights = np.linspace(0, 1, 50)
previous_best = ''
changes = 0
change_weight_tresholds = []
variant_scores = dict()
victors = []

for variable_vpt_weight in variable_vpt_weights:
    variable_performance_weight = 1 - variable_vpt_weight

    # Recalculate the weights using the current variable weights.
    recalculated_weights = {
        'Bus': variable_performance_weight * bandwith_weight * bus_weight,
        'Memory clock': variable_performance_weight * bandwith_weight * memory_clock_weight,
        'Memory': variable_performance_weight * bandwith_weight * memory_weight,
        'Shaders': variable_performance_weight * rendering_weight * shaders_weight,
        'TMUs': variable_performance_weight * rendering_weight * TMUs_weight,
        'ROPs': variable_performance_weight * rendering_weight * ROPs_weight,
        'GPU clock': variable_performance_weight * chipset_weight * GPU_clock_weight,
        'GPU Chip': variable_performance_weight * chipset_weight * GPU_chip_weight,
        'Released': variable_vpt_weight * released_weight,
        'Price': variable_vpt_weight * price_weight,
        'Manufacturer': manufacturer_weight
    }

    # Recalculate the variant scores.
    best_variant = -1
    best_utility = -1
    for variant_name in converted_data['Product Name']:
        # Assemble the variant.
        variant_dict = dict()
        for column in converted_data[converted_data['Product Name'] == variant_name].columns[1:]:
            variant_dict[column] = \
                converted_data[converted_data['Product Name'] == variant_name][column].to_list()[0]
        # Calculate the variant score.
        utility = score(variant_dict, recalculated_weights)

        # Check if current variant is best.
        if best_utility < utility:
            best_utility = utility
            best_variant = variant_name

        if variant_name not in variant_scores:
            variant_scores[variant_name] = [(variable_vpt_weight, utility)]
        else:
            variant_scores[variant_name].append((variable_vpt_weight, utility))

    # Store change and change treshold.
    if previous_best == '' or previous_best != best_variant:
        previous_best = best_variant
        victors.append(best_variant)
        changes += 1
        change_weight_tresholds.append(variable_vpt_weight)

print('Number of different victors: \n', changes)
print('Victors: \n', victors)
print('Victors occured at the following tresholds: \n', change_weight_tresholds)
```

```
Number of different victors:
 4
Victors:
 ['GeForce RTX 4090', 'Radeon RX 6750 XT', 'GeForce RTX 3060 Ti', 'GeForce RTX 3050 8 GB']
Victors occured at the following tresholds:
 [0.0, 0.4081632653061224, 0.5510204081632653, 0.5918367346938775]
```

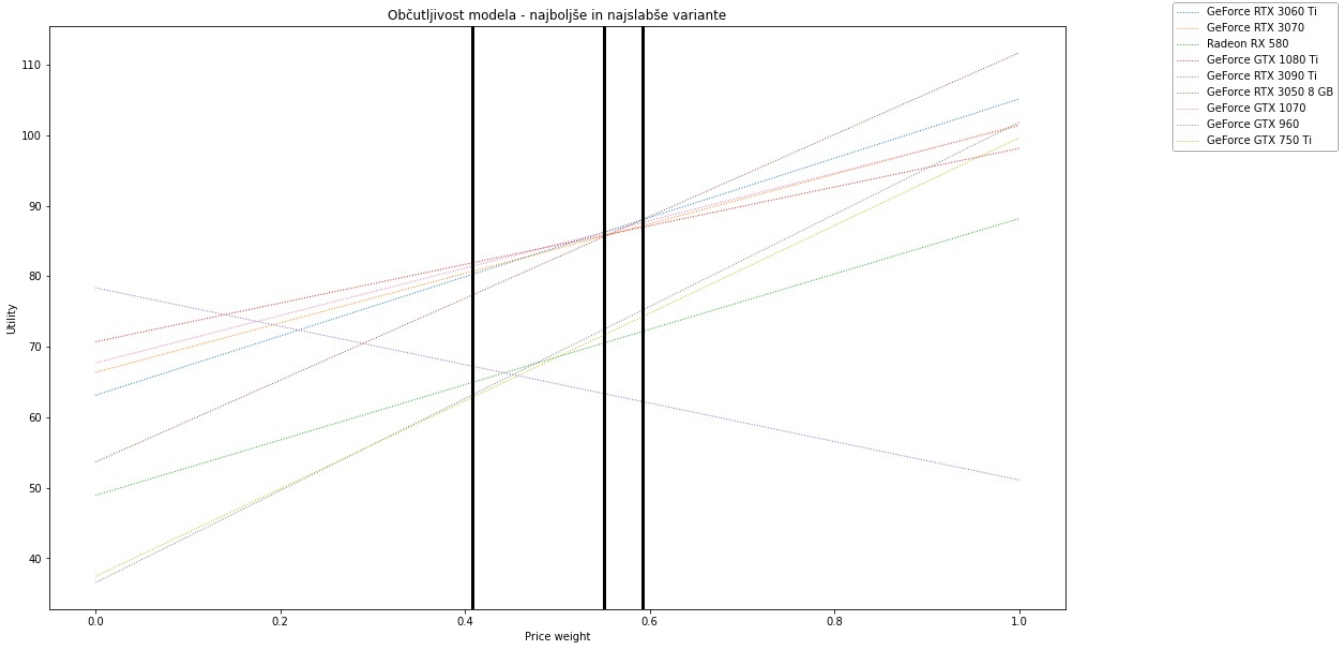
Grafična predstavitev občutljivosti

```
fig, ax = plt.subplots(figsize=(17,10))

ax.set_xlabel('Price weight')
ax.set_ylabel('Utility')
ax.set_title('Občutljivost modela')

for variant in variant_scores:
    x = [x for x, _ in variant_scores[variant]]
    y = [y for _, y in variant_scores[variant]]
    ax.plot(x, y, linewidth=1, linestyle='dotted', label=variant)

    for x in change_weight_tresholds[1:]:
        ax.axvline(x, color='k', linestyle='-', linewidth=3, alpha=0.7)

ax.legend(bbox_to_anchor=(1.1, 1.05))

plt.show()
```



In [184…

```python
# Draw less crowded graph - only represent best and worst variants.

fig, ax = plt.subplots(figsize=(17,10))

ax.set_xlabel('Price weight')
ax.set_ylabel('Utility')
ax.set_title('Občutljivost modela - najboljše in najslabše variante')

best_variants = [
    'GeForce GTX 1070',
    'GeForce GTX 1080 Ti',
    'GeForce RTX 3060 Ti',
    'GeForce RTX 3070',
    'GeForce RTX 3050 8 GB'
]
worst_variants = [
    'GeForce GTX 960',
    'GeForce GTX 750 Ti',
    'Radeon RX 580',
    'GeForce RTX 3090 Ti'
]

for variant in variant_scores:
    if variant in best_variants or variant in worst_variants:
        x = [x for x, _ in variant_scores[variant]]
        y = [y for _, y in variant_scores[variant]]
        ax.plot(x, y, linewidth=1, linestyle='dotted', label=variant)

        for x in change_weight_tresholds[1:]:
            ax.axvline(x, color='k', linestyle='-', linewidth=3, alpha=0.7)

ax.legend(bbox_to_anchor=(1.1, 1.05))

plt.show()
```



Opazimo lahko, da se zmagovalec skozi različno uteženo vrednostjo po času spremeni štirikrat, z višjo utežjo so boljše variante, ki imajo nižjo ceno in so izšle kasneje:

- Če je utež med 0 in 0.41, je zmagovalec NVIDIA GeForce RTX 4090, ki je najdražja varianta a ima tudi najboljšo zmogljivost.
- Če je utež med 0.41 in 0.55, je zmagovalec AMD Radeon RX 6750 XT
- Če je utež med 0.55 in 0.59 je zmagovalec NVIDIA GeForce RTX 3060 TI
- Če je uteć med 0.55 in 1 je zmagovalec NVIDIA GeForce RTX 3050 8 GB

Vidimo, da so pri višjih utežeh Vrednosti po času še vedno dobro ocenjene precej drage alternative, kar nakazuje tudi na pomembnost datuma izdaje, prav tako pa imajo vsi zmagovalci dokaj dobro zmogljivost.

Kaj-če analiza

Kaj če se cena variant zmanjša (npr. ujamemo popust pri prodajalcu, prodajalec se želi znebiti zaloge)? Za koliko bi se morala znižati cena, da se nam splača nakup alternativne variante, ali pa celo nakup najdražje variante?

Analizo sem izvedel tako, da sem ceno izbranih variant postopoma spuščal, ponovno zračunal oceno variante in preverjal, kdaj ocena variante postane višja od ocene najboljše variante.

In [185…
```
alternative_variant_u = data[data['Product Name'] == 'Radeon RX 6600'].copy()
# Most expensive variant has the worst price utility value.
most_expensive_variant_u = data[data['Product Name'] == 'GeForce RTX 4090'].copy()

best_variant_score = 71.616

# Perform what-if analysis on alternative variant.
price_change = np.linspace(alternative_variant_u['Price'].to_list()[0], 0, 30)
for price in price_change:
    # Get normalized data, replace price with actual value and renormalize it.
    changed_variant = converted_data[converted_data['Product Name'] == 'Radeon RX 6600'].copy()
    changed_variant['Price'] = price
    changed_variant['Price'] = changed_variant['Price'].apply(normalize_price)

    variant_dict = dict()
    for column in changed_variant.columns[1:]:
        variant_dict[column] = changed_variant[column].to_list()[0]

    value = score(variant_dict, actual_weights)
    if value > best_variant_score:
        real_price = data[data['Product Name'] == 'Radeon RX 6600']['Price'].to_list()[0]
        price_difference = real_price - price
        percentage_difference = price_difference / (real_price + price / 2) * 100
        print('Alternative variant:')
        print(' Score: ', value, \
            '\n Change in price: ', price_difference, \
                '\n Actual price: ',  price, \
                    '\n Percentage difference: ', percentage_difference, \
                        sep='')
        break

# Perfrom what-if analysis on the most expensive variant.
price_change = np.linspace(most_expensive_variant_u['Price'].to_list()[0], 0, 30)
for price in price_change:
    # Get normalized data, replace price with actual value and renormalize it.
    changed_variant = converted_data[converted_data['Product Name'] == 'GeForce RTX 4090'].copy()
    changed_variant['Price'] = price
    changed_variant['Price'] = changed_variant['Price'].apply(normalize_price)

    variant_dict = dict()
    for column in changed_variant.columns[1:]:
        variant_dict[column] = changed_variant[column].to_list()[0]

    value = score(variant_dict, actual_weights)
    if value > best_variant_score:
        real_price = data[data['Product Name'] == 'GeForce RTX 4090']['Price'].to_list()[0]
        price_difference = real_price - price
        percentage_difference = price_difference / (real_price) * 100
        print('Most expensive variant:')
        print(' Score: ', value, \
            '\n Change in price: ', price_difference, \
                '\n Actual price: ',  price, \
                    '\n Percentage difference: ', percentage_difference, \
                        sep='')
        break
```

```
Most expensive variant:
 Score: 72.19636663591874
 Change in price: 651.4827586206898
 Actual price: 2047.5172413793102
 Percentage difference: 24.13793103448276
```

Kot lahko vidimo, se nakup moje alternativne variante ne bi splačal v nobenem primeru. Najvrjetneje je to zato, ker ima ostale atribute

toliko slabše od najbolše variante. Alternativno pa bi se nakup najdražje variante splačal, če bi se cena zmanjšala za 651.5$ ali 24.13%.