Benchmark baz danych

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Rozdziały

1 Informacje wstępne

1.1 Założenia projektu

1. Zaprojektować schemat dokumentów JSON dla wybranego tematu. Należy mieć min 2 typy dokumentów na osobę w projekcie. Minimum jeden typ musi mieć dokumenty zagnieżdżone

2. Opracowany model, wraz z propozycją najważniejszych/najbardziej rozbudowanych poleceń należy zatwierdzić u wykładowcy (ew. poprawić wg. sugestii)

3. Dla każdego typu dokumentu wygenerować min 100 sensownych instancji. Jeden z typów powinien mieć minimum 500 instancji. Dane można generować automatami typu generatedata.com bądź napisać 4 skrypt w pythonie (dodatkowe punkty).

4. Tak przygotowane dokumenty należy zaimportować do:

   - Wybranej bazy NoSQL
   - PostgreSQLa do kolumn typu JSONB
   - PostgreSQLa przy jednoczesnej konwersji JSON na tabele

5. Wszystkie 3 procesy importowania należy udokumentować screenshotami i zapisanymi wykorzystanymi poleceniami

6. Należy utworzyć min 4 zapytania na osobę realizujące najważniejsze problemy wyszukiwania w tworzonej bazie.

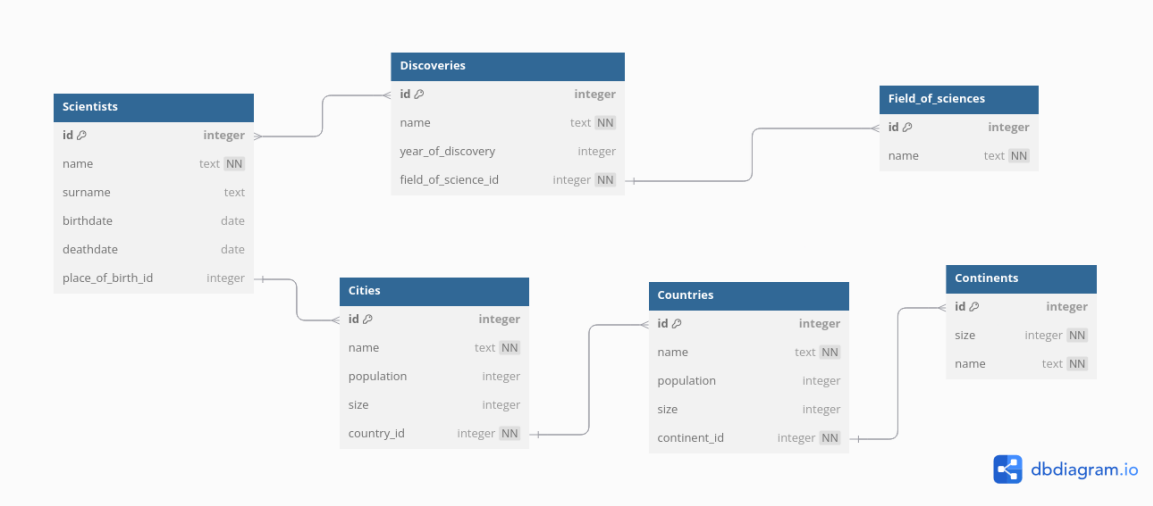
7. Każde z zapytań musi mieć 3 wersje dla 3 sytuacji z pkt 4.

8. Należy przeprowadzić eksperyment pomiaru czasu wykonania tych zapytań. Aby eksperyment był rzetelnie przeprowadzony, zarówno baza NoSQLowa, jak i PostgreSQL muszą operować w podobnych warunkach: albo obie bazy są postawione w osobnych dockerach, albo zainstalowane w tym samym OS, ale uruchamiane jedna na raz (proces instalacji musi być udokumentowany). Wyniki czasowe należy przedstawić w tabelce

1.2 Użyte technologie i sprzęt

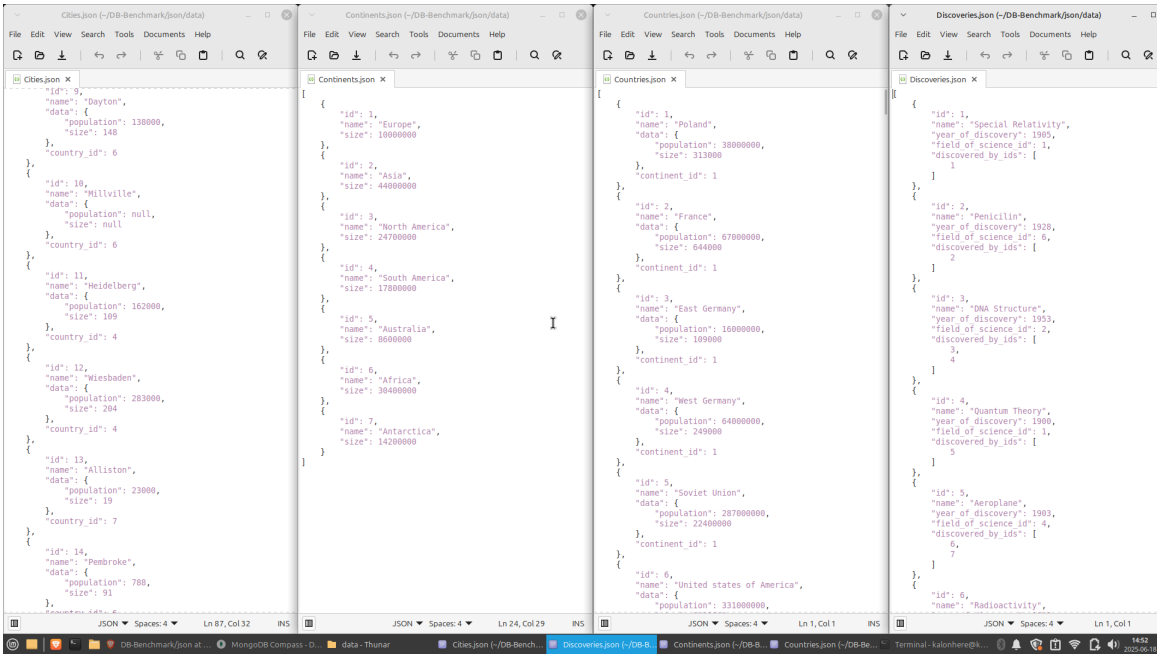
- PostgreSQL - wersja 16.9
- MongoDB - wersja 8.0.10
- Laptop:
  - OS - Linux Mint 22.1
  - CPU - Intel i7-9750H
  - GPU - Nvidia GTX 1660
  - RAM - 16GB 2667 MHz

1.3 Schemat logiczny bazy danych

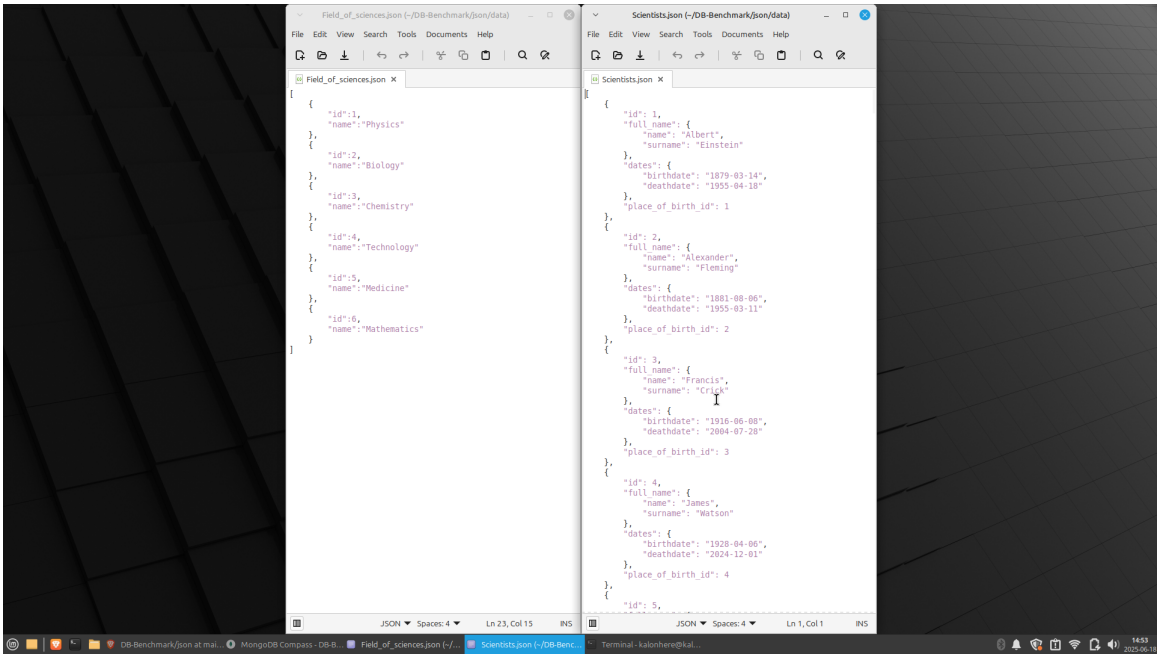


Zdjęcie. 1: *Schemat logiczny zrobiony w serwisie dbdiagram.io*

1.4 Przykładowe dane z plików JSON

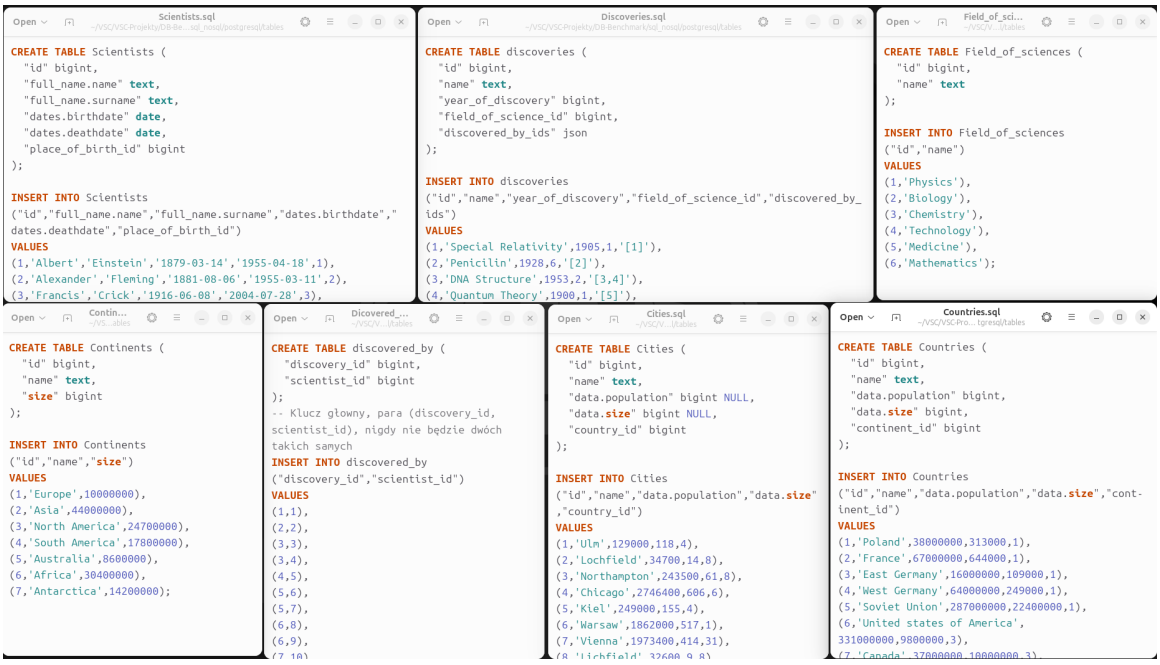


Zdjęcie. 2: *Pliki JSON od lewej: Cities, Continents, Countries, Discoveries*



Zdjęcie. 3: *Pliki JSON od lewej: Field_ of_ sciences, Scientists*

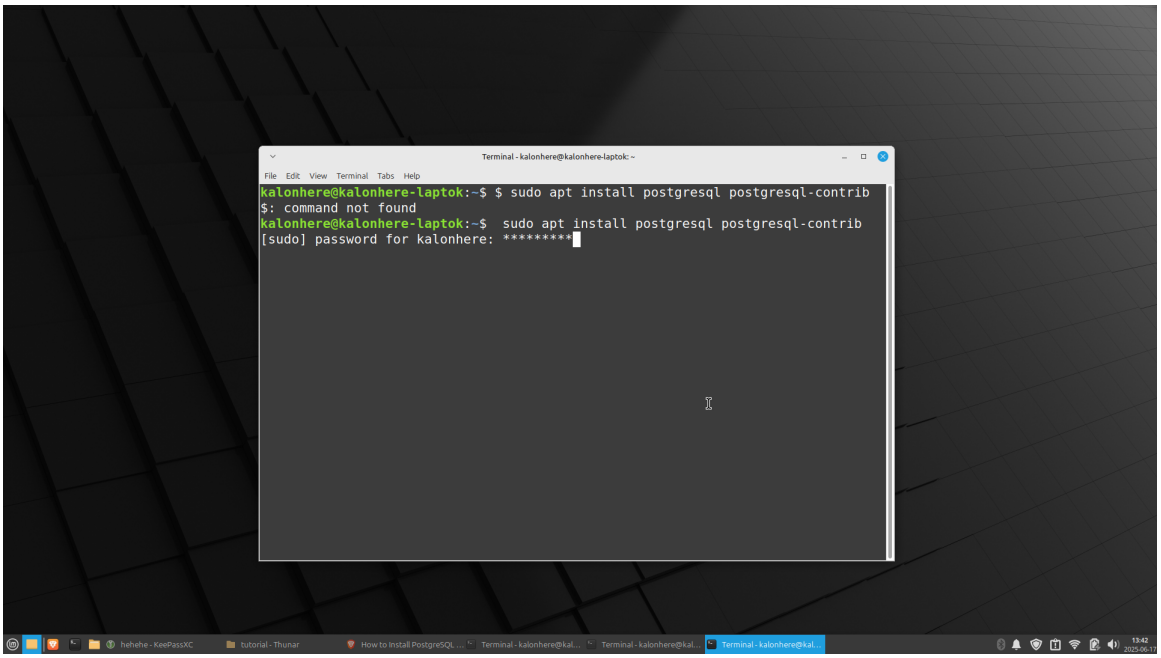
1.5 Baza danych i dane w PostgreSQL



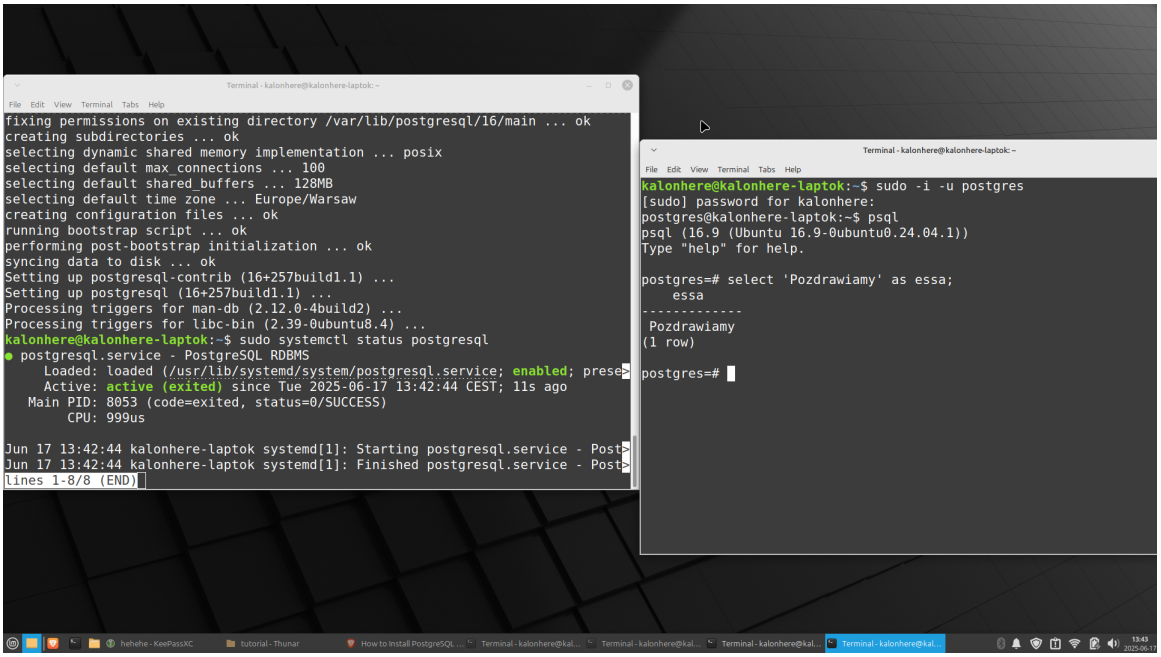
Zdjęcie. 4: *Wszystkie JSONy po konwersji na sql*

2 Instalacja baz danych

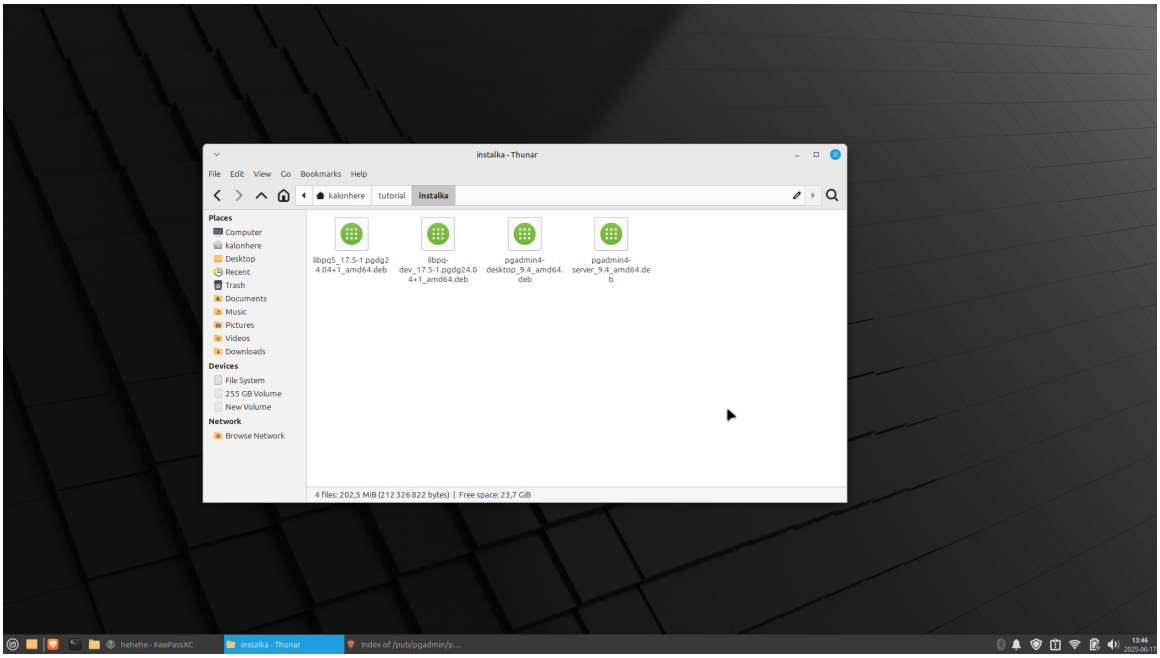
2.1 PostgreSQL



Zdjęcie. 5: *Instalacja za pomocą apt*

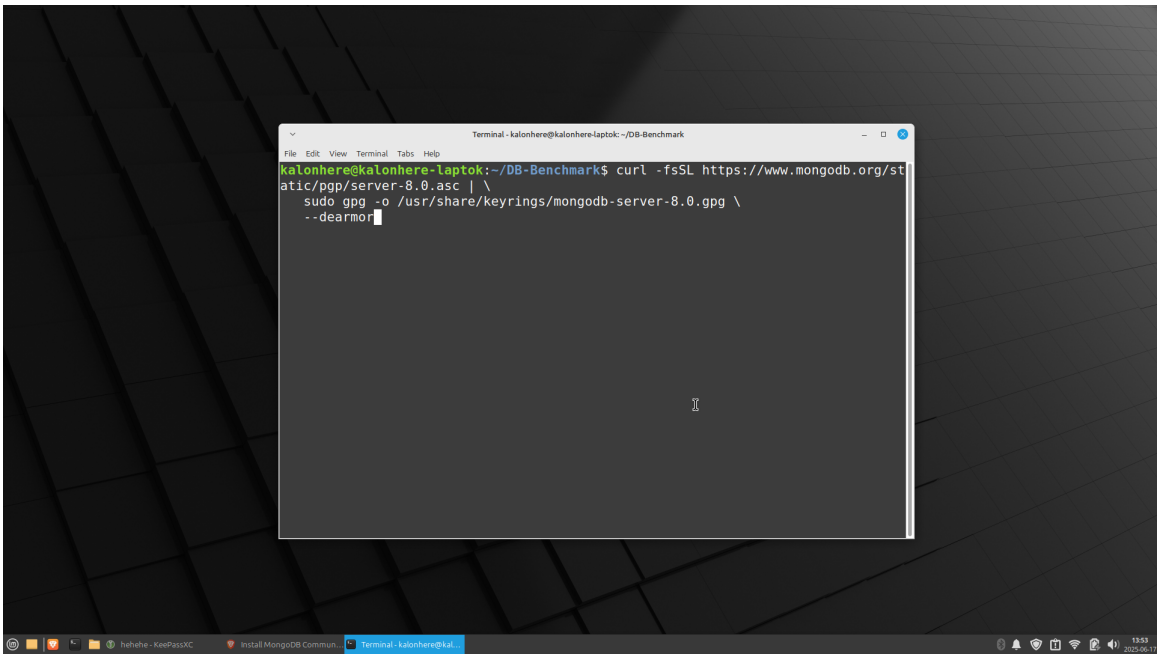


Zdjęcie. 6: *Po lewej - komenda systemctl aby sprawdzić czy działa, po prawej - logowanie na user, uruchomienie psqgl i test działania*

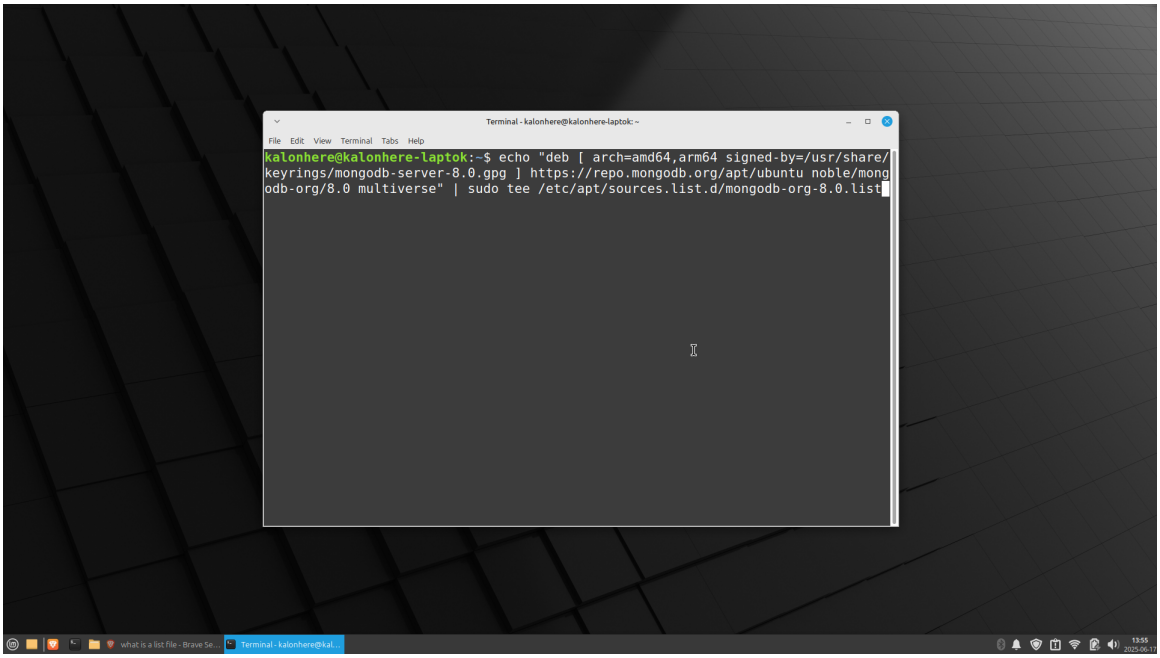


Zdjęcie. 7: *Instalacja pgadmina z serwera ftp PostgreSQL*

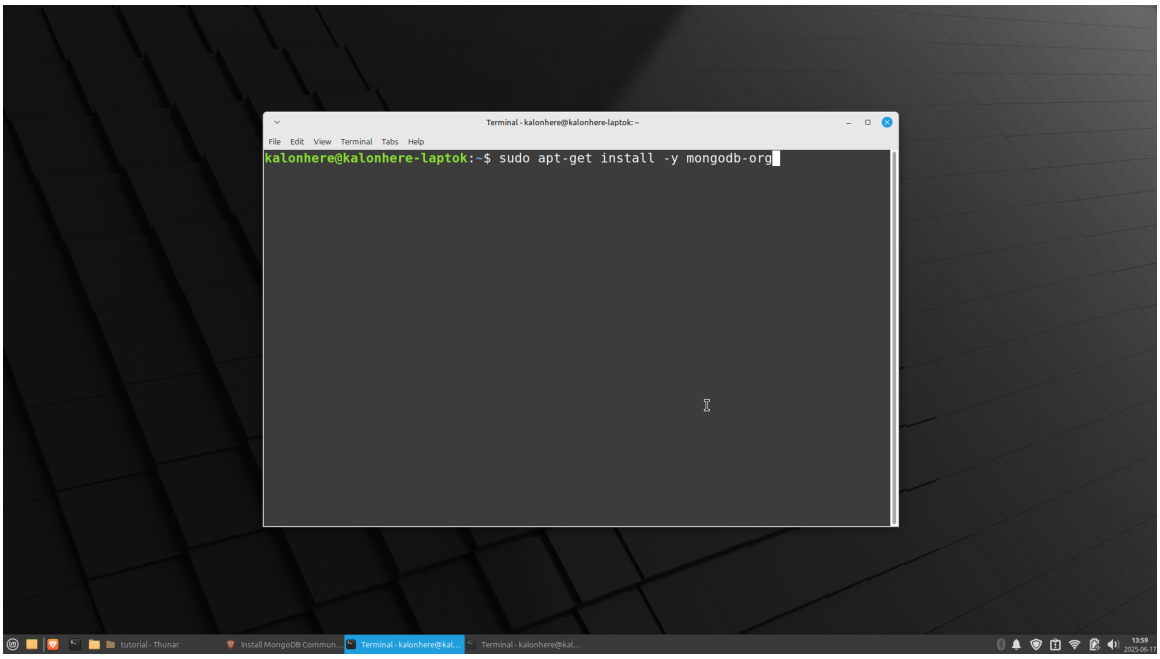
2.2 MongoDB



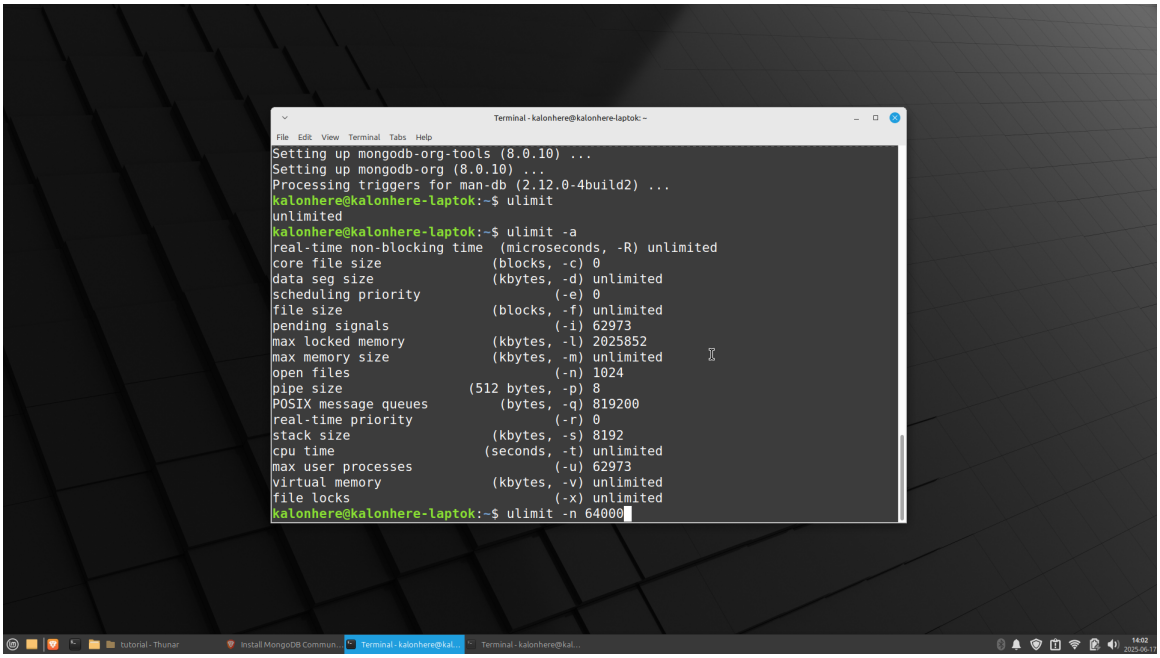
Zdjęcie. 8: *Importowanie kluczy gpg do MongoDB*



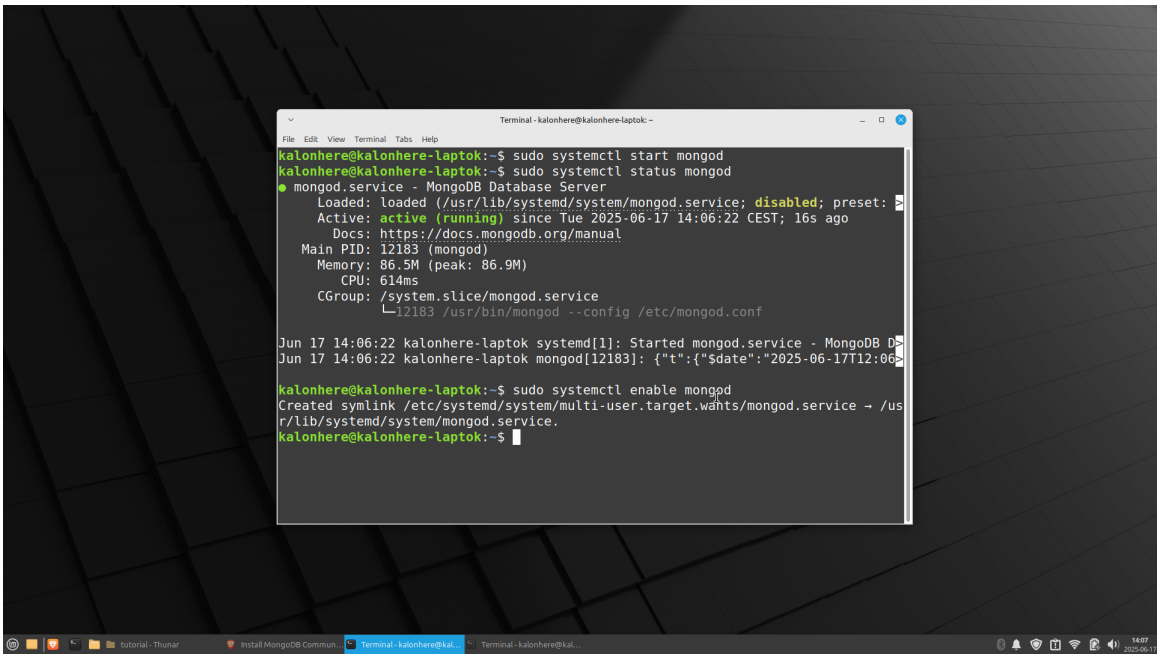
Zdjęcie. 9: *Stworzenie pliku z listą źródeł do pobierania repo/package*



Zdjęcie. 10: *Instalacja MongoDB*



Zdjęcie. 11: *Zwiększenie limitu otwartych plików z 1024 do 64000*



Zdjęcie. 12: *Uruchomienie MongoDB, sprawdzenie statusu i włączenie autouruchamiania*

3 Listy zapytań

3.1 Oryginalne pomysły zapytań

1. Wybierz naukowców którzy pochodzą z azji i odkryli więcej niż 5 rzeczy z biologii lub chemii
2. Wybierz państwo które ma najwięcej odkryć z fizyki oraz nazwa państwa kończy się na "a"
3. Zlicz ile odkryć z matematyki ma każdy kontynent
4. Znajdź naukowców którzy nie żyją i mają wiecej odkryć niż 3 z wszystkiego oprócz fizyki, dodatkowo wypisz liczbę ich odkryć poza fizyką
5. Znajdź miasto których naukowcy mają najwięcej odkryć w chemii
6. Znajdź najstarsze i najmłodsze odkrycie z ZSRR z chemii
7. Znajdź miasto które nie ma żadnych odkryć w biologii po 1960 roku
8. Znajdź średnią liczbę wszystkich odkryć na rok w każdym państwie w europie
9. Wypisz dziedzine w której każde państwo z azji dokonało najwięcej odkryć
10. Wypisz średnią liczbę odkryć na naukowca z każdego kontynetu
11. Znajdź państwo z największą średnią liczbą odkryć na osobę
12. Znajdź miasto z którego pochodzący naukowcy dokonali najwięcej odkryć z fizyki

3.2 Finalne zapytania

1. Wybierz państwo którego nazwa kończy się na "a" i ma najwięcej odkryć z fizyki
2. Znajdź najstarsze i najmłodsze odkrycie z USA z biologii
3. Znajdź państwa które mają odkrycia z biologii po 1960 roku
4. Znajdź średnią liczbę wszystkich odkryć na państwo w każdym kontynencie
5. Wypisz dziedzine w której każde państwo z europy dokonało najwięcej odkryć
6. Wypisz średnią liczbę odkryć na naukowca z każdego kontynetu
7. Znajdź państwo z największą średnią liczbą odkryć na kilometr kwadratowy
8. Znajdź miasto z którego pochodzi najwięcej fizyków

4 Zapytania w MongoDB

4.1 Zapytanie 1

```
[{$match: {
    name: { $regex: "a$", $options: "i" }
  }
},
{$lookup: {
    from: "Cities",
    localField: "id",
    foreignField: "country_id",
    as: "cities"
  }
},
{ $unwind: "$cities" },
{$lookup: {
    from: "Scientists",
    localField: "cities.id",
    foreignField: "place_of_birth_id",
    as: "scientists"
  }
},
{ $unwind: "$scientists" },
{$lookup: {
    from: "Discoveries",
    let: { scientistId: "$scientists.id" },
    pipeline: [
      {
        $match: {
          $expr: {
            $and: [
              { $eq: ["$field_of_science_id", 1] },
              { $in: ["$$scientistId", "$discovered_by_ids"] }
            ]
          }
        }
      }
    ],
    as: "discoveries"
  }
},
{ $unwind: "$discoveries" },
{$group: {
    _id: { country_id: "$id", country: "$name", discovery_id: "$discoveries.id", discovery_name: "$discoveries.name" }
  }
},
{$group: {
    _id: { country_id: "$_id.country_id", country: "$_id.country" },
    discoveries: { $addToSet: { id: "$_id.discovery_id", name: "$_id.discovery_name" } },
    count: { $sum: 1 }
  }
},
{ $sort: { count: -1 } },
{ $limit: 1 },
{$project: {
    _id: 0,
    country: "$_id.country",
    count: 1,
    discoveries: 1
  }
}]
```

4.2 Zapytanie 2

```
[{$match: {
    field_of_science_id: 2
  }
},
{$unwind: "$discovered_by_ids"
},
{$lookup: {
    from: "Scientists",
    localField: "discovered_by_ids",
    foreignField: "id",
    as: "scientist"
  }
},
{$unwind: "$scientist" },
{$lookup: {
    from: "Cities",
    localField: "scientist.place_of_birth_id",
    foreignField: "id",
    as: "birth_city"
  }
},
{$unwind: "$birth_city" },
{$match: {
    "birth_city.country_id": 6
  }
},
{$group: {
    _id: {
      id: "$id",
      name: "$name",
      year_of_discovery: "$year_of_discovery"
    }
  }
},
{$sort: { "_id.year_of_discovery": 1 } },
{$group: {
    _id: null,
    discoveries: { $push: "$_id" }
  }
},
{$project: {
    _id: 0,
    oldest: { $arrayElemAt: ["$discoveries", 0] },
    youngest: { $arrayElemAt: ["$discoveries", -1] }
  }
}]
```

4.3 Zapytanie 3

```
[{$match: {
        field_of_science_id: 2,
        year_of_discovery: { $gt: 1960 }
    }
},
    { $unwind: "$discovered_by_ids" },

{$lookup: {
    from: "Scientists",
    localField: "discovered_by_ids",
    foreignField: "id",
    as: "scientist"
  }
},
{ $unwind: "$scientist" },
{$lookup: {
    from: "Cities",
    localField: "scientist.place_of_birth_id",
    foreignField: "id",
    as: "city"
  }
},
{ $unwind: "$city" },
{$group: {
    _id: {
      country_id: "$city.country_id",
      discovery_id: "$id",
      discovery_name: "$name"
    }
  }
},
{$lookup: {
    from: "Countries",
    localField: "_id.country_id",
    foreignField: "id",
    as: "country"
  }
},
{$unwind: "$country" },
{$group: {
    _id: "$country.name",
    discoveries: { $addToSet: { id: "$_id.discovery_id", name: "$_id.discovery_name" } },
    count: { $sum: 1 }
  }
},
{$sort: { count: -1 } },
{$project: {
    _id: 0,
    country: "$_id",
    count: 1,
    discoveries: 1
  }
}]
```

4.4 Zapytanie 4

```
[{$lookup: {
    from: "Scientists",
    localField: "discovered_by_ids",
    foreignField: "id",
    as: "scientist"
  }
},
{ $unwind: "$scientist" },
{$lookup: {
    from: "Cities",
    localField: "scientist.place_of_birth_id",
    foreignField: "id",
    as: "city"
  }
},
{ $unwind: "$city" },
{$lookup: {
    from: "Countries",
    localField: "city.country_id",
    foreignField: "id",
    as: "country"
  }
},
{ $unwind: "$country" },
{$lookup: {
    from: "Continents",
    localField: "country.continent_id",
    foreignField: "id",
    as: "continent"
  }
},
{ $unwind: "$continent" },
{$group: {
    _id: {
      continent_id: "$continent.id",
      continent_name: "$continent.name",
      country_id: "$country.id",
      country_name: "$country.name",
      discovery_id: "$id"
    }
  }
},
{$group: {
    _id: {
      continent_id: "$_id.continent_id",
      continent_name: "$_id.continent_name",
      country_id: "$_id.country_id",
      country_name: "$_id.country_name" },
    discoveries_count: { $sum: 1 }
  }
```

```
},
{$group: {
    _id: {
      continent_id: "$_id.continent_id",
      continent_name: "$_id.continent_name"},
    average_discoveries_per_country: { $avg: "$discoveries_count" },
    countries: {
      $push: {
        country_id: "$_id.country_id",
        country_name: "$_id.country_name",
        discoveries_count: "$discoveries_count"
      }
    }
  }
},
{
  $project: {
    _id: 0,
    continent_id: "$_id.continent_id",
    continent_name: "$_id.continent_name",
    average_discoveries_per_country: { $round: ["$average_discoveries_per_country", 2] },
  }
},
{$sort: { continent_name: 1 } }
]
```

4.5 Zapytanie 5

```
[{$unwind: "$discovered_by_ids"
},
{$lookup: {
    from: "Scientists",
    localField: "discovered_by_ids",
    foreignField: "id",
    as: "scientist"
  }
},
{ $unwind: "$scientist" },
{$lookup: {
    from: "Cities",
    localField: "scientist.place_of_birth_id",
    foreignField: "id",
    as: "city"
  }
},
{ $unwind: "$city" },
{$lookup: {
    from: "Countries",
    localField: "city.country_id",
    foreignField: "id",
    as: "country"
  }
},
{ $unwind: "$country" },
{$match: {
    "country.continent_id": 1
  }
},
{$group: {
    _id: {
      country_id: "$country.id",
      country_name: "$country.name",
      field_of_science_id: "$field_of_science_id"
    },
    discoveries_count: { $sum: 1 }
  }
},
{$sort: {
    "_id.country_name": 1,
    discoveries_count: -1
  }
},
{$group: {
    _id: "$_id.country_name",
    field_of_science_id: { $first: "$_id.field_of_science_id" },
    discoveries_count: { $first: "$discoveries_count" }
  }
},
```

```
{$lookup: {
    from: "Field_of_sciences",
    localField: "field_of_science_id",
    foreignField: "id",
    as: "science"
  }
},
{ $unwind: "$science" },
{$project: {
    _id: 0,
    country: "$_id",
    field_of_science: "$science.name",
    discoveries_count: 1
  }
},
{$sort: { country: 1 } }
```

4.6 Zapytanie 6

```
[{$lookup: {
    from: "Cities",
    localField: "place_of_birth_id",
    foreignField: "id",
    as: "city"
  }
},
{ $unwind: "$city" },
{$lookup: {
    from: "Countries",
    localField: "city.country_id",
    foreignField: "id",
    as: "country"
  }
},
{ $unwind: "$country" },
{$lookup: {
    from: "Continents",
    localField: "country.continent_id",
    foreignField: "id",
    as: "continent"
  }
},
{ $unwind: "$continent" },
{$lookup: {
    from: "Discoveries",
    let: { scientistId: "$id" },
    pipeline: [
      {
        $match: {
          $expr: { $in: ["$$scientistId", "$discovered_by_ids"] }
        }
      }
    ],
    as: "discoveries"
  }
},
{$addFields: {
    discoveries_count: { $size: "$discoveries" }
  }
},
{$group: {
    _id: "$continent.name",
    total_discoveries: { $sum: "$discoveries_count" },
    scientists_count: { $sum: 1 }
  }
},
{$project: {
    _id: 0,
    continent: "$_id",
    avg_discoveries_per_scientist: {
      $cond: [
        { $eq: ["$scientists_count", 0] },
        0,
        { $round: [{ $divide: ["$total_discoveries", "$scientists_count"] }, 2] }
      ]
    },
    total_discoveries: 1,
    scientists_count: 1
  }
},
{$sort: { continent: 1 } }
]
```

4.7 Zapytanie 7

```
[{$unwind: "$discovered_by_ids"
},
{$lookup: {
    from: "Scientists",
    localField: "discovered_by_ids",
    foreignField: "id",
    as: "scientist"
  }
},
{$unwind: "$scientist" },
{$lookup: {
    from: "Cities",
    localField: "scientist.place_of_birth_id",
    foreignField: "id",
    as: "city"
  }
},
{$unwind: "$city" },
{$lookup: {
    from: "Countries",
    localField: "city.country_id",
    foreignField: "id",
    as: "country"
  }
},
{$unwind: "$country" },
{$group: {
    _id: {
      country_id: "$country.id",
      country_name: "$country.name",
      discovery_id: "$id"
    },
    country_size: { $first: "$country.data.size" }
  }
},
{$group: {
    _id: {
      country_id: "$_id.country_id",
      country_name: "$_id.country_name"
    },
    discoveries_count: { $sum: 1 },
    country_size: { $first: "$country_size" }
  }
},
{$addFields: {
    avg_discoveries_per_km2: {
      $cond: [
        { $gt: ["$country_size", 0] },
        { $divide: ["$discoveries_count", "$country_size"] },
        null
      ]
    }
  }
},
{$sort: { avg_discoveries_per_km2: -1 } },
{$limit: 1 },
{$project: {
    _id: 0,
    country: "$_id.country_name",
    discoveries_count: 1,
    size: "$country_size",
    avg_discoveries_per_km2: { $round: ["$avg_discoveries_per_km2", 6] }
  }
}]
```

4.8 Zapytanie 8

```
[{$lookup: {
    from: "Discoveries",
    let: { scientistId: "$id" },
    pipeline: [
      {
        $match: {
          field_of_science_id: 1,
          $expr: { $in: ["$$scientistId", "$discovered_by_ids"] }
        }
      }
    ],
    as: "physics_discoveries"
  }
},
{$match: {
    "physics_discoveries.0": { $exists: true }
  }
},
{$group: {
    _id: "$place_of_birth_id",
    physicists_count: { $sum: 1 }
  }
},
{$lookup: {
    from: "Cities",
    localField: "_id",
    foreignField: "id",
    as: "city"
  }
},
{$unwind: "$city" },
{$sort: { physicists_count: -1 } },
{$limit: 1 },
{$project: {
    _id: 0,
    city: "$city.name",
    country_id: "$city.country_id",
    physicists_count: 1
  }
}]
```

5 Zapytania w PostgreSQL

5.1 Zapytanie 1

```sql
select * from scientists
inner join discovered_by on scientists.id = discovered_by.scientist_id
inner join discoveries on discovered_by.discovery_id = discoveries.id
inner join field_of_sciences on discoveries.field_of_science_id = field_of_sciences.id
where place_of_birth_id in
(select id from cities where country_id in
(select id from countries where name like '%a'))
and field_of_sciences.name like 'Physics';
```

5.2 Zapytanie 2

```sql
select discoveries.name, discoveries.year_of_discovery
from scientists
inner join discovered_by on scientists.id = discovered_by.scientist_id
inner join discoveries on discovered_by.discovery_id = discoveries.id
inner join field_of_sciences on discoveries.field_of_science_id = field_of_sciences.id
inner join cities on scientists.place_of_birth_id = cities.id
inner join countries on cities.country_id = countries.id
where lower(countries.name) = 'united states of america'
  and lower(field_of_sciences.name) = 'biology'
  and discoveries.year_of_discovery = (
    select min(discoveries.year_of_discovery)
    from scientists
    inner join discovered_by on scientists.id = discovered_by.scientist_id
    inner join discoveries on discovered_by.discovery_id = discoveries.id
    inner join field_of_sciences on discoveries.field_of_science_id = field_of_sciences.id
    inner join cities on scientists.place_of_birth_id = cities.id
    inner join countries on cities.country_id = countries.id
    where lower(countries.name) = 'united states of america'
      and lower(field_of_sciences.name) = 'biology'
  )
union all
select discoveries.name, discoveries.year_of_discovery
from scientists
inner join discovered_by on scientists.id = discovered_by.scientist_id
inner join discoveries on discovered_by.discovery_id = discoveries.id
inner join field_of_sciences on discoveries.field_of_science_id = field_of_sciences.id
inner join cities on scientists.place_of_birth_id = cities.id
inner join countries on cities.country_id = countries.id
where lower(countries.name) = 'united states of america'
  and lower(field_of_sciences.name) = 'biology'
  and discoveries.year_of_discovery = (
    select max(discoveries.year_of_discovery)
    from scientists
    inner join discovered_by on scientists.id = discovered_by.scientist_id
    inner join discoveries on discovered_by.discovery_id = discoveries.id
    inner join field_of_sciences on discoveries.field_of_science_id = field_of_sciences.id
    inner join cities on scientists.place_of_birth_id = cities.id
    inner join countries on cities.country_id = countries.id
    where lower(countries.name) = 'united states of america'
      and lower(field_of_sciences.name) = 'biology'
  );
```

5.3 Zapytanie 3

```
select * from scientists
inner join discovered_by on scientists.id = discovered_by.scientist_id
inner join discoveries on discovered_by.discovery_id = discoveries.id
inner join field_of_sciences on discoveries.field_of_science_id = field_of_sciences.id
where place_of_birth_id in
(select id from cities where country_id in
(select id from countries))
and field_of_sciences.name like 'Biology'
and year_of_discovery > 1960;
```

5.4 Zapytanie 4

```
select
  continents.name as continent,
  avg(country_discoveries.discovery_count) as average_discoveries_per_country
from
  (
    select
      countries.id as country_id,
      count(*) as discovery_count
    from
      scientists
      join countries on scientists.place_of_birth_id = countries.id
      join discovered_by on scientists.id = discovered_by.scientist_id
    group by
      countries.id
  ) as country_discoveries
  join countries on country_discoveries.country_id = countries.id
  join continents on countries.continent_id = continents.id
group by
  continents.name;
```

5.5 Zapytanie 5

```sql
with country_discoveries as (
  select
    lower(countries.name) as country,
    lower(field_of_sciences.name) as field,
    count(distinct discoveries.id) as discovery_count
  from scientists
  inner join cities on scientists.place_of_birth_id = cities.id
  inner join countries on cities.country_id = countries.id
  inner join discovered_by on scientists.id = discovered_by.scientist_id
  inner join discoveries on discovered_by.discovery_id = discoveries.id
  inner join field_of_sciences on discoveries.field_of_science_id = field_of_sciences.id
  where countries.continent_id = 1
  group by countries.name, field_of_sciences.name
), max_discoveries as (
  select
    country,
    max(discovery_count) as max_count
  from country_discoveries
  group by country
)
select
  cd.country,
  cd.field,
  cd.discovery_count
from country_discoveries cd
inner join max_discoveries md
  on cd.country = md.country and cd.discovery_count = md.max_count
order by cd.country, cd.field;
```

5.6 Zapytanie 6

```sql
select
  lower(continents.name) as continent,
  round(
    count(distinct discovered_by.discovery_id)::numeric
    / count(distinct scientists.id), 6
  ) as average_discoveries_per_scientist
from scientists
inner join cities on scientists.place_of_birth_id = cities.id
inner join countries on cities.country_id = countries.id
inner join continents on countries.continent_id = continents.id
inner join discovered_by on scientists.id = discovered_by.scientist_id
group by continents.name
order by continent asc;
```

5.7 Zapytanie 7

```sql
select
  lower(c.name) as country,
  round(cd.discovery_count::numeric / c."data.size", 6) as discoveries_per_km2
from
  countries c
  join (
    select
      co.id as country_id,
      count(distinct db.discovery_id) as discovery_count
    from
      scientists s
      join cities ci on s.place_of_birth_id = ci.id
      join countries co on ci.country_id = co.id
      join discovered_by db on s.id = db.scientist_id
    group by
      co.id
  ) cd on c.id = cd.country_id
where
  c."data.size" is not null and c."data.size" > 0
order by
  discoveries_per_km2 desc
limit 1;
```

5.8 Zapytanie 8

```sql
select
  lower(cities.name) as city,
  count(distinct scientists.id) as physicist_count
from scientists
inner join cities on scientists.place_of_birth_id = cities.id
inner join discovered_by on scientists.id = discovered_by.scientist_id
inner join discoveries on discovered_by.discovery_id = discoveries.id
inner join field_of_sciences on discoveries.field_of_science_id = field_of_sciences.id
where lower(field_of_sciences.name) = 'physics'
group by cities.name
order by physicist_count desc
limit 1;
```

6 Porównanie czasowe zapytań

Po wykonaniu każdego zapytania odpowiednio, otrzymaliśmy następujące wyniki:

Zapytanie	MongoDB	PostrgreSQL	PostreSQL-JSONB
1	22ms	57ms	n/a
2	4ms	59ms	n/a
3	1ms	57ms	n/a
4	41ms	67ms	n/a
5	49ms	80ms	n/a
6	54ms	80ms	n/a
7	70ms	79ms	n/a
8	42ms	67ms	n/a

7 Uwagi końcowe

- Brak udokumentowania procesu instalacji MongoDB Compass - zapomnieliśmy
- Brak udokumentowania procesu importowania do MongoDB - jedno kliknięcie w MongoDB Compass
- Brak udokumentowania procesu importowania do PostgreSQL JSONB - proszę zrozumieć, Filip po tym będzie miał traumę
- Brak zrobienia testów z poleceń PostreSQL JSONB - brak czasu i trauma Filipa po importowaniu (udało się zimporotwać ale trauma wygrała i nie udało się zrobić poleceń)
- Brak udokumentowania procesu importowania do PostgreSQL - proste wklejenie sql z pliku do pgAdmin
- Słabe/Bezsensowne zapytania - nie dostaliśmy akcepta na czas :c
- Wiemy, że zrobiliśmy kiepskie JSONy w sensie do MongoDB ale chcieliśmy móc je prosto przekonwertować do PostgreSQL i nie mieliśmy nigdy doświedczenie w projektowaniu ich jako bazy danych
- Wszystkie JSONy pisaliśmy sami, zawierają odkrycia z 20 wieku, miasta i państwa posiadają najnowsze dane na temat populacji i wielkości, co do ich lokacji to korzystaliśmy z mapy z okresu zimnej wojny
- Cały projekt z plikami - https://github.com/Aleks-Zielinski/DB-Benchmark