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Neo4j: A graph database

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What is a database?

- Organized collection of structured information, or data, stored in a computer system
- Usually controlled by a database management system (DBMS)
- Together, data and DBMS, are referred to as a *database system*, often shortened to just database
- Data stored in a database can be easily accessed, managed, modified, updated, controlled, and organized

Types ofdatabases

- Many types of databases, that mainly differ on data models
  - E.g., relational databases, NoSQL databases, graph database
- The best type depends on how you intend to use data
- Relational databases
  - The most common type
  - Data is modeled in rows and columns in a series of tables to make processing and data querying efficient
  - Use Structured Query Language (SQL) for writing and querying data

Neo4j: a graph database

- Graph database: a database designed to treat relationships between data as equally important to data itself
  - Purpose-built to store and navigate relationships
  - Uses nodes to store data entities, and links to store relationships between entities
- Neo4j: an open-source, native graph database

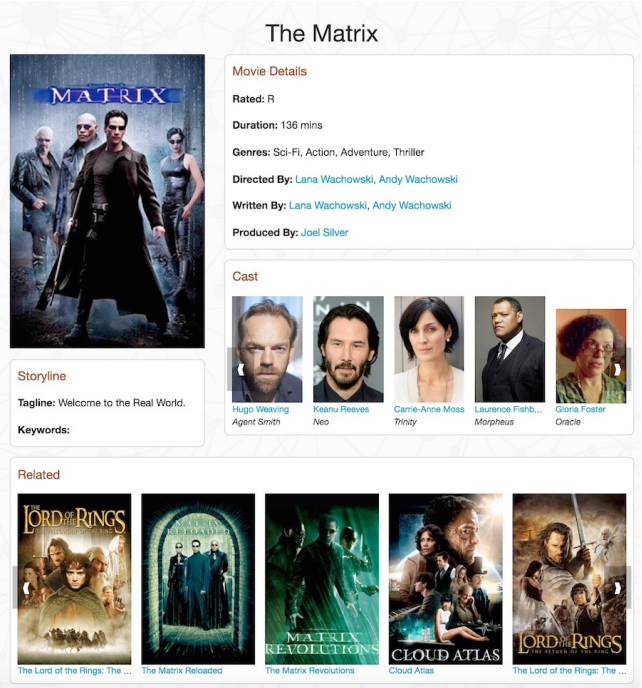
Graph data model

- Powerful data model
  - Designed to treat relationships between data
  - Focus on visual representation of information (more human-friendly)

- Data model based on graph (network) structure
  - *Nodes* are the entities and have a set of attributes
  - *Links* are the relationships between the entities
    - E.g.: an author writes a book
    - In Neo4j links are directed

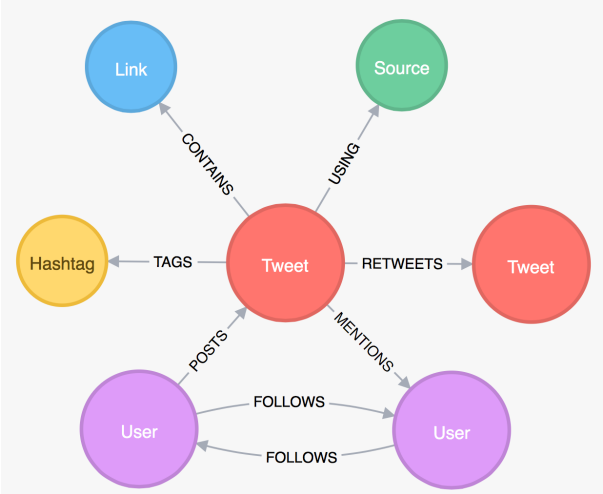
Graph data model: movies example

- How can we model information regarding the movie The Matrix?



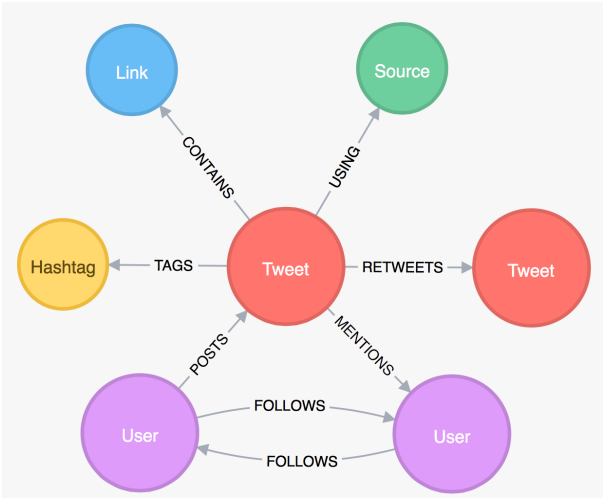
Graph data model: Twitter example

- How can we represent Twitter data and relationships?
- Choice depends also on what we want to analyze: let's assume social media activity
- Nodes in the graph model
  - `User`: represents a Twitter user
  - `Tweet`: represents a tweet
  - `Hashtag`: represents a hashtag
  - `Link`: represents a shared link in a tweet
  - `Source`: represents the platform used by Twitter users to tweet from



Graph data model: Twitter example

- Relationships in the graph:
  - `POST` relationship between a `User` and a `Tweet`: indicates that this user is the tweet author
  - `RETWEETS` relationship between two `Tweets`: indicates the first `Tweet` retweets the second `Tweet`
  - `TAGS` relationship between a `Tweet` and a `Hashtag`
  - `FOLLOWS` relationship between two `Users`: indicates the first `User` follows the second `User`
  - `MENTIONS` relationship between `Tweet` and `User`: indicates that the `Tweet` mentions the `User`

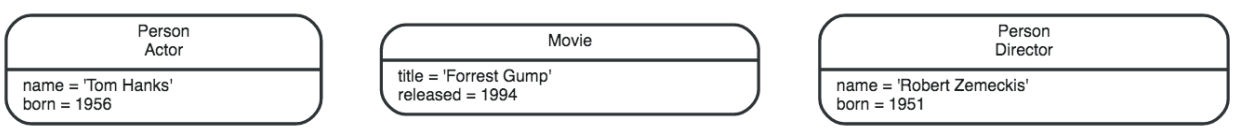


Suitable use cases for graph databases

- Good for applications where:
  - you need to model entities and relationships between them
  - and the focus is on querying for relationships between entities and analyzing relationships
- Examples of applications
  - Social networks
  - Recommender systems
  - Pattern recognition
  - Dependency analysis

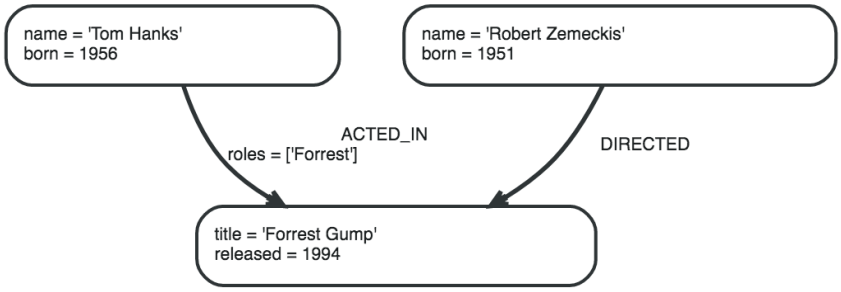
Neo4j: concepts

- Graph concepts
  - Nodes, relationships, properties, and labels
- We use nodes to represent entities
  - A node can have properties and labels
  - A node can have relationships to other nodes, including itself
- Nodes and relationships have individual attributes called properties
- Properties consist of key-value pairs, e.g.,
  - name = ‘Tom Hanks’, born = 1956
  - title = ‘Forrest Gump’, released = 1994



Neo4j: concepts

- Nodes can be tagged with labels (i.e., node types)
  - Labels are used to shape the domain by grouping nodes into sets, so that all nodes with a given label belong to the same set (e.g., Actor and Director are labels for Person nodes)
- Relationships connect nodes, are unidirectional and can have properties
  - E.g., ACTED_IN, DIRECTED
- Properties are key-value pairs that are used to add qualities to nodes and relationships



Neo4j: Cypher

- **Cypher**: Neo4j's graph query language
- Allows users to store and retrieve data from Neo4j
  neo4j.com/docs/getting-started/current/cypher-intro/
- It is a declarative way to query the graph powered by traversals and other techniques
  - A traversal navigates through the graph to find paths
    - Starts from starting nodes to related nodes, finding answers to queries
  - A path is one or more nodes with connecting relationships, typically retrieved as a query or traversal result
- It is a textual declarative query language
  - Uses a form of ASCII art to represent graph-related patterns
  - E.g., `(a)-[:LIKES]->(b)`

Cypher syntax: node

- Cypher uses a pair of parentheses `( )`, usually containing a text string, to represent a node

```
(varname:Label { p_name: p_value, ... } )
```

  - `( )` represents a node
  - `varname` (optional) is a variable that we can assign to the node and use it later in a query to refer to that node
  - `Label` (prefixed with a colon `:`) declares node's type (or *label*)
  - Node's properties are represented as a list of key/value pairs, enclosed within a pair of `{ }`
  - E.g., to represent a Person node with name and year of birth

```
(keanu:Person {name:'Keanu Reeves', born:1964})
```

varname

Label

list of properties as `key:'value'` pairs

Cypher syntax: relationship

- Cypher uses a pair of dashes `--` to represent an undirected relationship. Directed relationships have an arrowhead at one end `<--` `-->`
  - It is possible to create only directed relationship, although they can be queried as undirected
- Bracketed expressions `[ ]` are used to add details:
  - We can assign a variable (e.g., `role`) also to a relationship and use it later in a query
  - The relationship's type (e.g., `:ACTED_IN`) is analogous to the node's label
  - The relationship's properties (e.g., `roles`) are analogous to the node properties

```
(keanu)-[role:ACTED_IN {roles:['Neo']}]->(TheMatrix)
```

Cypher syntax: pattern variables

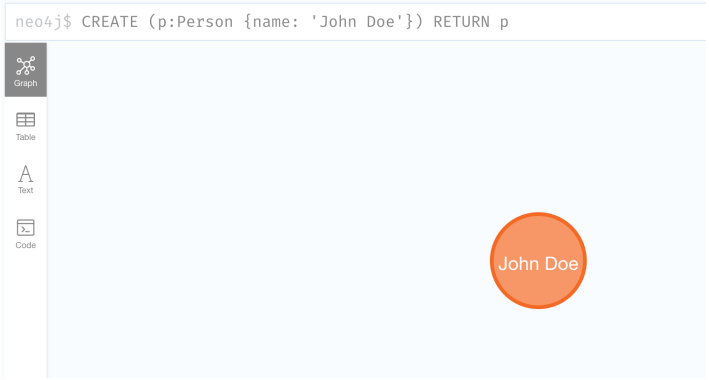
- To increase modularity and reduce repetition, Cypher allows patterns to be assigned to variables
  - This allows the matching paths to be inspected, used in other expressions, etc.
- E.g., `acted_in` is a variable

```
acted_in = (:Person)-[:ACTED_IN]->(:Movie)
```


Cypher syntax: CREATE

- Use `CREATE` to insert data (nodes and relationships) in the database
  - Example: create a node with label Person and property name with value John Doe
  - `RETURN` defines what to include in the query result

```
CREATE (p:Person {name: 'John Doe'})
RETURN p
```



Cypher syntax: CREATE

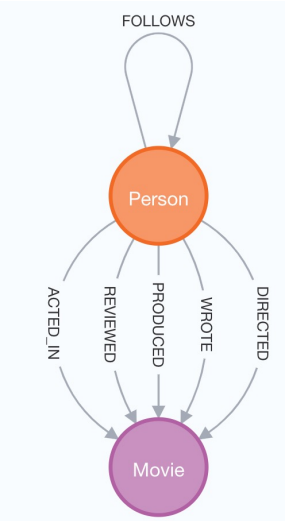
- Use `CREATE` to insert data (nodes and relationships)
  - Example: create a Person node and a Movie node and their relationship

```
CREATE (a:Person {name: 'Tom Hanks', born: 1956})-
[r:ACTED_IN {roles: ['Forrest']}]->(m:Movie {title:
'Forrest Gump', released: 1994})
CREATE (d:Person {name: 'Robert Zemeckis', born:
1951})-[:DIRECTED]->(m)
RETURN a, d, r, m
```


Cypher syntax: analyze graph model

- Once we have created data (or we use a pre-populated database), we can display the graph model in terms of node types and relationship types

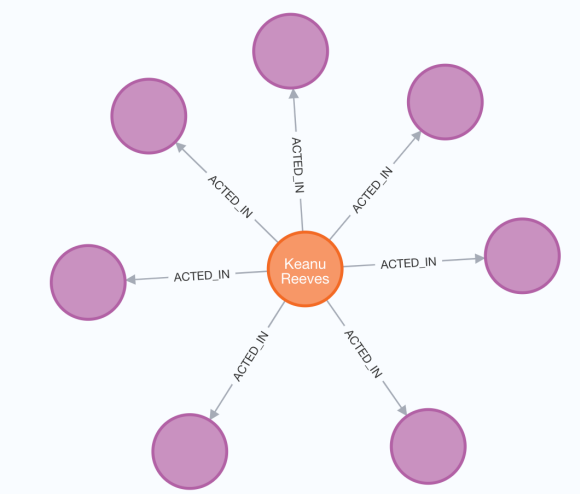
```
call db.schema.visualization()
```



Cypher syntax: MATCH

- Use `MATCH` to read data from database
  - `MATCH` specifies the patterns to search for in the database
  - E.g., find which movies Keanu Reeves has acted in

```
MATCH (keanu {name:'Keanu Reeves'})-[:ACTED_IN]->
(movies:Movie) RETURN keanu, movies
```



Cypher syntax: MATCH

- Use `MATCH` to read data from database
  - E.g., find which movies Keanu Reeves has acted in but now return only the movies title

```
MATCH (keanu {name:'Keanu Reeves'})-[:ACTED_IN]->
(movies:Movie) RETURN movies.title
```

```
neo4j$ MATCH (keanu {name:'Keanu Reeves'})-[:ACTED_IN]→ (movies:Movie) RETURN movies.title
```

	movies.title
1	"The Matrix"
2	"The Matrix Reloaded"
3	"The Matrix Revolutions"
4	"The Devil's Advocate"
5	"The Replacements"
6	"Johnny Mnemonic"
7	"Something's Gotta Give"

Cypher syntax: MATCH and WHERE

- Use `WHERE` to add constraints to the patterns in a `MATCH` clause
  - E.g., find the movie with title The Matrix

```
MATCH (m:Movie)
WHERE m.title = 'The Matrix'
RETURN m
```


Cypher syntax: DELETE

- Use `DELETE` to delete a node, e.g.,

```
MATCH (p:Person {name: 'John Doe'})
DELETE p
```

- Node cannot be deleted if it participates in a relationship. To remove also relationships, we need to detach the node, delete it and its relationships:

```
MATCH (d:Person {name: 'Greg Kinnear'})
DETACH DELETE d;
```

Cypher syntax: Relationship pattern length

Relationship pattern length:

```
(a)-[*2]->(b)
```

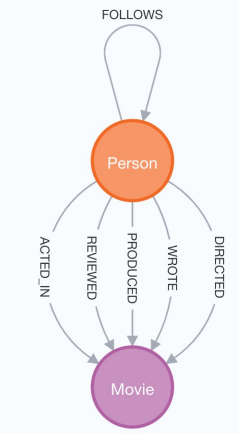
It is possible to specify a length (e.g., 2) in the relationship description of a pattern

It can be a variable length:

`*3..5` (between 3 and 5)
`*3..` (greater than 3)
`*..5` (less than 5)
`*` (any length)

Example: movie database

- Let's use as case study the movie database provided by Neo4j as sandbox with pre-populated data
  - Basic dataset of *Actors* acting in *Movies*
  - Available at neo4j.com/sandbox
  - Data model of the movie database is



Example: movie database

- The goal of our analysis is to show recommendations for other actors to work with
  - By following the meaningful relationships between actors and movies, we can determine:
    - Occurrences of actors working together
    - Frequency of actors working with one another
    - Movies they have in common in the graph
- Let's start with simple queries and then increase their complexity

Some basic queries

- Let's find a single actor like *Tom Hanks*

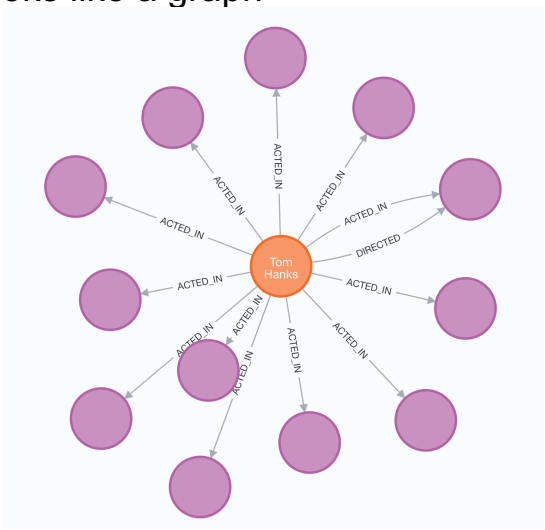
```
MATCH (tom:Person {name: 'Tom Hanks'}) RETURN tom
```

Some basic queries

- Let's retrieve all Tom Hanks' movies by starting from Tom Hanks node and following ACTED_IN relationships

```
MATCH (tom:Person {name: 'Tom Hanks'})-[r:ACTED_IN]->(movie:Movie) RETURN tom, r, movie
```

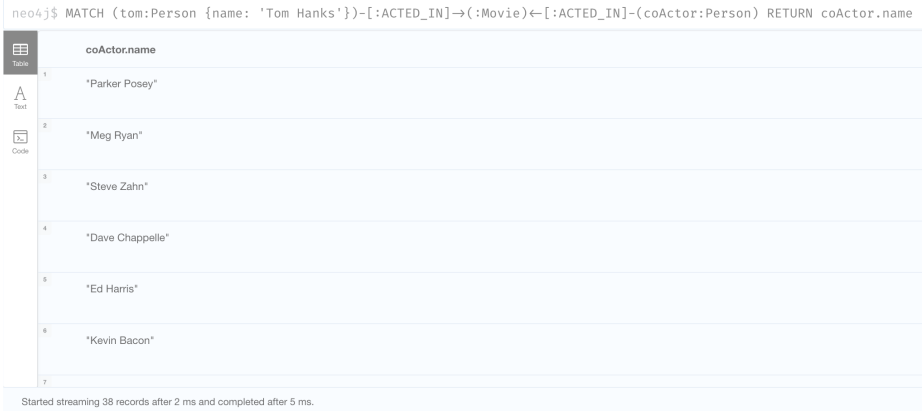
  - The query result looks like a graph



Some basic queries

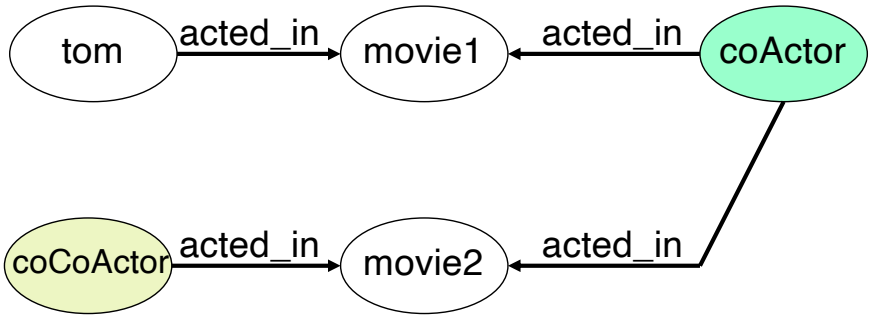
- Tom Hanks has colleagues who acted with him in his movies, let's find these co-actors:


```
MATCH (tom:Person {name: 'Tom Hanks'})-[:ACTED_IN]->(:Movie)<-[:ACTED_IN]-(coActor:Person) RETURN coActor.name
```



Recommendation queries

- Let's find Tom's co-co-actors, i.e., the second-degree actors in Tom's network



Recommendation queries

- Let's find the co-co-actors, i.e., the second-degree actors in Tom's network. This will show us all the actors Tom may not have worked with yet, and we can specify a criterium to be sure he hasn't directly acted with that person

```
MATCH (tom:Person {name: 'Tom Hanks'})-[:ACTED_IN]-
>(movie1:Movie)<-[:ACTED_IN]-(coActor:Person)-
[:ACTED_IN]->(movie2:Movie)<-[:ACTED_IN]-
(coCoActor:Person) WHERE tom <> coCoActor AND NOT
(tom)-[:ACTED_IN]->(:Movie)<-[:ACTED_IN]-
(coCoActor) RETURN coCoActor.name
```

Recommendation queries

- In the query result a few names appear multiple times, because there are multiple paths to follow from *Tom Hanks* to these actors

Recommendation queries

- Let's see which co-co-actors appear most often in Tom's network: we can take frequency of occurrences into account by counting the number of paths between *Tom Hanks* and each coCoActor and ordering them by highest to lowest value

```
MATCH (tom:Person {name: 'Tom Hanks'})-[:ACTED_IN]-
>(movie1:Movie)<-[:ACTED_IN]-(coActor:Person)-
[:ACTED_IN]->(movie2:Movie)<-[:ACTED_IN]-
(coCoActor:Person) WHERE tom <> coCoActor AND NOT
(tom)-[:ACTED_IN]->(:Movie)<-[:ACTED_IN]-
(coCoActor) RETURN coCoActor.name, count(coCoActor)
as frequency ORDER BY frequency DESC LIMIT 5
```

Recommendation queries

- The query result

```
neo4j$ MATCH (tom:Person {name: 'Tom Hanks'})-[:ACTED_IN]→(movie1:Movie)←[:ACTED_IN]-(coActor:Person)-[:ACTED_IN]→
       (movie2:Movie)←[:ACTED_IN]-(coCoActor:Person) WHERE tom <> coCoActor AND NOT (tom)-[:ACTED_IN]→(:Movie)←
       [:ACTED_IN]-(coCoActor) RETURN coCoActor.name, count(coCoActor) as frequency ORDER BY frequency DESC LIMIT 5
```

Table | Text | Code

	coCoActor.name	frequency
1	"Tom Cruise"	5
2	"Zach Grenier"	5
3	"Keanu Reeves"	4
4	"Kelly McGillis"	3
5	"Anthony Edwards"	3

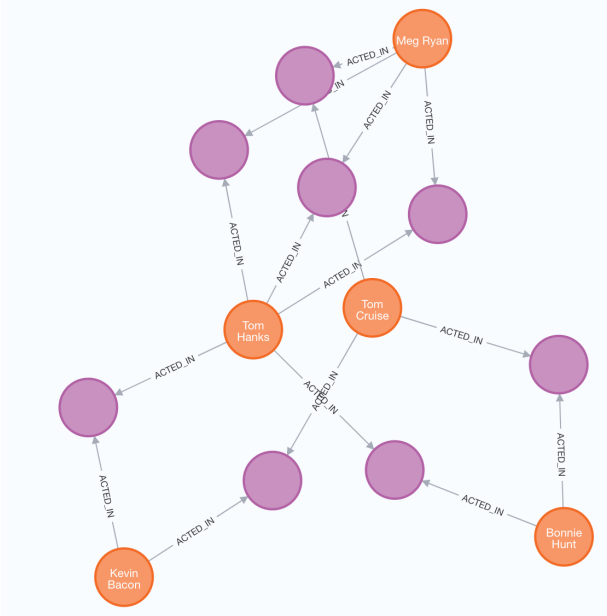
Recommendation queries

- One of the most frequent “co-co-actors” is *Tom Cruise*. Now let’s see which movies and actors are between the two Toms so we can find out who can introduce them

```
MATCH (tom:Person {name: 'Tom Hanks'})-[:ACTED_IN]-
>(movie1:Movie)<-[:ACTED_IN]-(coActor:Person)-
[:ACTED_IN]->(movie2:Movie)<-[:ACTED_IN]-
(cruise:Person {name: 'Tom Cruise'}) WHERE NOT
(tom)-[:ACTED_IN]->(:Movie)<-[:ACTED_IN]-(cruise)
RETURN tom, movie1, coActor, movie2, cruise
```

Recommendation queries

- The query result: there are multiple paths between the two Toms
  - And there is Kevin Bacon in one of the paths! See the six degrees of Kevin Bacon game en.wikipedia.org/wiki/Six_Degrees_of_Kevin_Bacon



Neo4j sandboxes

- As project for the course, you are going to use one of the Neo4j sandboxes
  - Online tool, not requiring a local installation neo4j.com/sandbox
  - Pre-populated with domain data and focus on use-case specific queries
    - See sandbox description on the course web site
  - Each sandbox is available for at least 3 days after creation and can be extended for 7 additional days before expiration; after the additional days, you need to restart the sandbox from scratch (in this case, you will lose new data you have saved into the database)