Neo4j Graph Data Modeling

Design efficient and flexible databases by optimizing the power of Neo4j

Mahesh Lal
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Mahesh Lal is a developer who has experience with various technologies. In 2011, while working on a social network for a client, he discovered the power of graphs, specifically Neo4j. Since then, he has been working with multiple clients across various domains for modeling their data as a graph. Currently working for ThoughtWorks, India, he is trying to help his clients look at their search problems in the form of a graph.

I would like to thank my reviewers, Daniel Vaughan, Sonal Raj, and Patrick Baumgartner, for giving me valuable feedback. I am grateful to Jim Webber and Pramod Sadalge for guiding me through this journey. I am indebted to my colleagues at ThoughtWorks for believing in me. Finally, I'd like to thank my family, who always inspire me to improve.
About the Reviewers

Patrick Baumgartner works as a passionate software craftsman at 42talents and builds software with Java/JEE, Spring Framework, OSGi, NoSQL databases, and other open source technologies. Since he began working with Neo4j in 2010, he sees the whole world as one big connected graph.

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As a Spring trainer and Neo4j master instructor, he conducts various training and workshops on the topic, is an active speaker at conferences and events, and lectures at technical colleges. In his free time, he likes to explore Rik's Beer Graph or his own Single Malt Whisky Graph and tries to find routes to beautiful places.

Patrick has coauthored the German book, *OSGi für Praktiker*, with Bernd Weber and Oliver Braun and reviewed *Scala - Objektfunktionale Programmierung* by Oliver Braun.

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I would like to thank my dearest girlfriend, Carmen, for supporting me in all my adventures.
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He has pursued engineering in computer science and loves to work on community projects. He has been a research fellow at IISc Bangalore and has taken up projects on graph computations using Neo4j and Storm. Sonal has been a speaker at PyCon India and local meetups about Neo4j, and has also published articles and research papers for leading magazines and international journals. He has contributed to several open source projects. Presently, Sonal works at Goldman Sachs.

He is the author of Neo4j High Performance and has reviewed titles on Storm and Neo4j.

I am grateful to the author for patiently listening to my critiques, and I’d like to thank the open source community for keeping their passions alive and contributing to such remarkable projects. A special thank you to my parents, without whom I never would have grown to love learning as much as I do.

Daniel Vaughan has worked as a software developer for over 15 years and is still learning every day. He first started using Neo4j in 2010, and currently works for the European Bioinformatics Institute, Hinxton, Cambridge, UK. He is married to Michelle and lives in the quaint market town of Saffron Walden.

Daniel has previously authored Ext GWT 2.0, Beginner's Guide and worked on the Spring Web Services 2, Cookbook, both by Packt Publishing.

His website is http://www.danielvaughan.com and you can find him on Twitter at @DanielVaughan.
To my family, who inspire me to shed fear, reach high, and be sure.
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Preface

Graph databases have been gaining traction for a long time now and companies have adopted them for various use cases. Neo4j, the world’s leading graph database, has been at the forefront of this trend and is widely used in production by companies that are world leaders in their respective domains. Advice on the usage of Neo4j using Cypher (the Neo4j query language), performance tuning of Neo4j, and general information can be sourced from various sources, including, but not limited to, blogs, the Neo4j website, the Neo4j mailing list, as well as books written by authors on these subjects. However, there is limited information regarding modeling information in Neo4j. This book aims to address this gap by giving examples of how various scenarios can be modeled in Neo4j. By sticking to a nonsocial graph example, this book steers clear of the stereotypical use case of graph databases. While we use Neo4j as an example to discuss graph database modeling, the concepts discussed can be applied to any graph database. We believe this book to be a useful tool for anyone wishing to understand graph database modeling.

What this book covers

Chapter 1, Graphs Are Everywhere, introduces you to the logical data representation of a property graph model, the various use cases of graph databases, and the advantages of using graph databases in general and Neo4j in particular.

Chapter 2, Modeling Flights and Cities, introduces you to basic modeling in Neo4j by discussing how flights and cities can be modeled in a graph database. We then create cities and flights in Neo4j using Cypher.

Chapter 3, Formulating an Itinerary, discusses some basic querying using Cypher for the purpose of creating a light itinerary from the existing data in Neo4j.

Chapter 4, Modeling Bookings and Users, discusses how to represent, in a graph database, a data model that is traditionally implemented in a RDBMS by modeling bookings in Neo4j.
Chapter 5, Refactoring the Data Model, covers refactoring the data model to accommodate changes in the business using Cypher. We do this as a multistep process and demonstrate how simple it is in Neo4j to change the data model.

Chapter 6, Modeling Communication Chains, discusses how communication chains can be modeled in Neo4j. This also covers how we can represent temporal relationships using this modeling technique, which allows for efficient retrieval of data while maintaining the integrity of the relationships between various pieces of information.

Chapter 7, Modeling Access Control, focuses on how access control lists can be modeled in Neo4j. This also discusses how hierarchies and groups can be modeled in Neo4j.

Chapter 8, Recommendations and Analysis of Historical Data, demonstrates the construction of queries to recommend cities and hotels to travelers using the data that we have in the database. This also analyzes some historical data to discover patterns in the database. This chapter demonstrates queries that would normally require some heavy lifting in an RDBMS.

Chapter 9, Wrapping Up, is the final chapter and talks about potential issues that you might run into while using Neo4j or a graph database, and also how modeling for a current problem isn't future-proof.

What you need for this book
To be able to learn from this book effectively, you must have Neo4j 2.2.3 (or higher) installed on your machine. Neo4j runs on Windows, Linux, and Mac OS X machines. The queries in this book have also been tested with Neo4j 2.3.0-M02.

Who this book is for
If you are a developer who wants to understand the fundamentals of modelling data in Neo4j and how it can be used to model full-fledged applications, then this book is for you. Some understanding of domain modelling may be advantageous, but is not essential.
Conventions

In this book, you will find a number of text styles that distinguish between different kinds of information. Here are some examples of these styles and an explanation of their meaning.

Code words in text, database table names, folder names, filenames, file extensions, pathnames, dummy URLs, user input, and Twitter handles are shown as follows: "The MATCH clause is used to match a path having the specified node and relationship types."

A block of code is set as follows:

```
neo4j-sh (?)$ CREATE CONSTRAINT ON (user:User) ASSERT user.email IS UNIQUE;
```

**New terms** and **important words** are shown in bold like this: "A city can have multiple categories and will be connected to all categories that it has by a :KNOWN_FOR relationship."

Warnings or important notes appear in a box like this.

Tips and tricks appear like this.

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Questions

If you have a problem with any aspect of this book, you can contact us at questions@packtpub.com, and we will do our best to address the problem.
Graphs are all around us. Each time we access the Internet, the data packets travel across a network of routers, switches, and cables and deliver what we have requested. While representing key concepts/objects in a problem and defining relationships or interactions between the concepts/objects involved, we generally draw bubbles or boxes to denote the objects, and arrows between those objects to represent the interactions or relationships. We use a similar notation while drawing a map to explain routes to others. The beauty of these notations, such as bubbles and arrows, is their expressiveness, a property that is usually lost when we obfuscate the model into records and tables. Graphs allow us to discover information and ease the modeling pain, which eventually makes our life smoother. To be able to use graphs better, we will need to understand a few basic concepts related to a graph database.

In this chapter, we will explore the following:

- Graphs in mathematics
- The property graph model
- Reasons for using a graph database
- Usage of graphs—some obvious and some not-so-obvious graph problems
- Advantages of using Neo4j

We chose Neo4j to explain graph data modeling in this book. However, the modeling concepts discussed here will apply to any graph database.

A few readers might be experienced Neo4j users and if you fall into this category, you might want to skip this chapter. However, if you are new to Neo4j or want a brief refresher, please carry on.
Graphs in mathematics
A graph is a mathematical structure of objects in which some pairs of objects are connected by links. The objects are denoted by abstractions called nodes (also known as vertices) and their links are represented by relationships (also known as edges). The relationships might be directed where it makes semantic sense in one particular direction. In cases where the semantics work in both directions, we can safely use undirected relationships to denote the link.

![Graph diagram](image)

Figure 1.1: Edges, vertices, directionality

In *Figure 1.1*, we have three actors or entities, Alice, Bob, and London, which are represented as nodes. The links between them are denoted by relationships. Alice is married to Bob and Bob is married to Alice. Both true, hence we represent *Is Married To* as an **undirected** relationship. However, Alice lives in London is represented by a directed relationship, *Lives In*, from Alice to London. This is because London lives in Alice cannot be true.
The property graph model

In Neo4j, we use a property graph model to represent information. The property graph model is an extension of the graphs from mathematics. The following figure gives an example of how data from Figure 1.1 can be represented in Neo4j:

![Figure 1.2: Nodes, relationships and properties](image)

The preceding figure introduces the following concepts that we use to model a property graph:

- **Nodes**: Entities are modelled as nodes. In Figure 1.2, London, Bob, Alice are all entities.

- **Labels**: These are used to represent the role of the node in our domain. A node can have multiple labels at the same time. Apart from adding more meaning to nodes, labels are also used to add constraints and indices that are local to the particular label. In the preceding figure, :Person and :Location are the two labels that we used. We can add an index or constraint on name for each of these labels, which will result in two separate indices—one for :Location and the other for :Person.
• **Relationships:** These depict directed, semantically relevant connections between two nodes. A relationship in Neo4j will always have a start node, an end node, and a single type. While relationships need to be created with a direction, we can ignore the direction while traversing them. :LIVES_IN and :IS_MARRIED_TO in Figure 1.2 are relationship types.

• **Properties:** These are key-value pairs that contain information about the node or relationship. In the previous figure, **name** and **since** are both properties that divulge more information about the node or relationship they are associated with. Neo4j can accept any [Java Virtual Machine (JVM)](https://www.oracle.com/java/technologies/javase-jdk11-jre.html) type as a property, including but not limited to, date, string, double, and arrays.

This property graph model allows us to model data as close to the real world as possible.

The resultant model is simpler and more expressive. It also explicitly calls out relationships. In contrast to an RDBMS, which uses foreign keys to imply relationships, having them explicitly defined allows us to retrieve data by traversing relationships to find the information we need. This is a deliberate, practical algorithmic approach that uses the connectedness of data, rather than relying on some index lookups or joins to find the related data. Explicit relationships also make the property graph model a natural fit for most problem domains, as they are interconnected.

**Storage – native graph storage versus non-native graph storage**

As with all database management systems, graph databases have the concept of storage and query engines, which deal with persistence and queries over connected data. The query engine of the database is responsible for running the queries and retrieving or modifying data. The query engine exposes the graph data model through Create, Read, Update, and Delete operations (commonly referred to as CRUD). Storage deals with how the data is stored physically and how it is represented logically when retrieved. Its knowledge can help in choosing a graph database.
Relationships are an important part of any domain model and need to be traversed frequently. In a graph database, the relationships are explicit rather than inferred. Making relationships explicit is achieved either via the query engine working on a non-native graph storage (such as RDBMS, column stores, document stores) or using a native graph storage.

In a graph database relying on non-native graph storage, relationships need to be inferred at runtime. For example, if we want to model a graph in an RDBMS, our processing engine will have to infer the relationships using foreign keys and reify the relationships at runtime. This problem is computationally expensive and is infeasible for traversing multiple relationships because of the recursive joins involved. There are other graph databases in which NoSQL stores such as HDFS, column stores such as Cassandra, or documents are used to store data and expose a Graph API. Though there are no joins in a graph database using NoSQL stores, the database still has to use index lookups. In cases where non-native storage is used, the query engines have to make more computational effort.

Neo4j uses a native graph storage. Each node has a handle to all the outgoing relationships it has and each relationship, in turn, knows its terminal nodes. At runtime, to find neighboring nodes, Neo4j doesn't have to do an index lookup. Instead, neighboring nodes can be identified by looking at the relationships of the current node. This feature is called index-free adjacency. Index-free adjacency is mechanically sympathetic and allows the Neo4j query engine to have a significant performance boost while traversing the graph.

Reasons to use graph databases
Every morning when we check our Facebook feed, we are welcomed by a stream of updates from friends and news. Using information about how data is connected and matching it with our individual preferences, Facebook builds a stream of activities from our network that are relevant and interest us. LinkedIn does something similar while suggesting jobs within our network. When we fire up Google Maps or some application such as TomTom or Sygic maps and start navigating to a destination, we use the data that represents connections of various intersections within the city, and work out how best to traverse it. While shopping online, products are recommended to us based on how closely they are connected to what we have already bought or similar products that others have bought. We leverage connected data more and more every day without realizing it.
When dealing with connected data, a graph database gives us the following advantages:

- The query performance of a graph database is a few orders of magnitude better than RDBMS or other NoSQL alternatives. As the dataset grows, RDBMS join performance deteriorates because of the ever-increasing size of the join tables. On the other hand, graph traversals are localized to a portion of the graph. So query execution time is proportional to the number of nodes visited, rather than being proportional to the overall amount of data stored. This makes the query performance fairly constant over time even though the data might increase exponentially.

- Flexibility and agility are major considerations in today's world where business needs are constantly evolving. Developers need to have a tool that allows them to incrementally think of the model rather than locking down the data model before they start coding. Graph databases allow for addition of relationships, node types, and properties without making any changes to the existing queries. We can connect the model incrementally, thereby allowing for more sophisticated querying. This flexibility also means fewer migrations. Even in case of changes to the data model, migrations are relatively pain free and can be done without taking the database offline for a long time, thus helping teams deliver software faster while concentrating on the domain rather than managing infrastructure and communication.

- Lesser ambiguity leads to better models. Since graph databases are schema-less, the schema is dictated by the application and hence is better validated. It allows for better design thinking by developers since there is no ambiguity of the domain model compared to how it is stored in tables.

- The design to delivery time is reduced. From a developer's standpoint, one of the best features of a graph database is that it is whiteboard friendly. We can make a data model on a whiteboard and not worry about trying to translate it to a set of tables, which don't necessarily represent the data model as is. This allows the developers to concentrate on development rather than translation, thereby saving time.

While all that has been said might seem like jargon, it boils down to economics. Graph databases make more economic sense when the data is highly connected.
What to use a graph database for

Let's start by citing a few problem statements that are more suited to graph databases.

Routing is a graph problem and much research has been done in that respect. One of the leading delivery services in the world uses a Neo4j-based solution to route packages in real time based on information being collected worldwide.

Social networks are problems suited for graphs since they leverage the connections of users to fetch data and decide on what is accessible and what isn't. Facebook, in particular, uses its graph search and has exposed it to the users to enable them to make better searches. Facebook relies heavily on the graph of people and their friends to curate the feed.

Recommendation is again a graph problem that can be solved using graph databases. While companies such as eBay originally relied on MySQL, they eventually turned to Neo4j.

While routing, social networks and recommendations are all obvious graph problems, companies have solved a host of problems by fitting the data into graphs in the recent past.

Search, for example, doesn't come across as a graph problem and is not a very intuitive one. However, Google uses its Knowledge Graph to give you search results based on how well connected a piece of content is to the term being searched. More recently, Facebook has leveraged its social graph to help search become better.

Medical research is another domain where graphs are being used. Medical data is highly interconnected and hence can benefit greatly from the use of graph databases. Companies are now using graph databases for drug discovery and storing medical information.

Storage of ontologies is increasingly being solved using graph databases, which are rapidly finding applications in machine learning and analytics. Companies are also using graph databases in domains such as energy supply and transportation.
Choosing Neo4j for exploring graph databases

Neo4j is a fast, native graph database that satisfies Atomicity, Consistency, Isolation, Durability (ACID) properties. Through usage of transactions, developers can ensure that the failure of a transaction leaves the database's state unchanged ensuring atomicity. Any change to the database doesn’t destroy data, ensuring consistency. Data modified by a transaction is isolated from other transactions till it is committed. Since Neo4j is a persistent graph database, the results of a committed transaction can always be retrieved, thus making it durable.

It started off supporting the TinkerPop stack. More information about the TinkerPop stack can be found at http://www.tinkerpop.com.

Neo4j provides numerous modeling and technical affordances, which are valuable when building real-world systems such as:

- Neo4j is the most mature graph database and has been in production round the clock since 2003. Neo4j is open source with an enormous community. The Neo4j development team is highly engaged with that community so that the features and bugs are rapidly addressed. Neo4j provides native graph storage that enables its engine to perform native graph processing. From the query language to disks, everything is mechanically sympathetic to the transactional storage and rapid retrieval of graph data.

- Cypher is a very expressive query language used to retrieve data from Neo4j. While it is superficially similar to SQL in some respect, Cypher is the only declarative query language that is built ground-up for humane yet performant graph queries and writes. The Neo4j Java API can be used on JVM-based languages as a more imperative and performant method of querying. This gives the best of both worlds by supporting imperative and declarative querying. (Neo4j plans to move away from supporting Gremlin in the long run, and currently Gremlin is supported through a plugin). Neo4j is open source and allows plugins to enhance or add functionalities, and there is a vibrant ecosystem of tooling around the core database.

- Any Cypher statement that updates the graph is run within a transaction. If a transaction exists, the newly fired Cypher query will be run in it. If no transaction exists, then the statement will itself be transactional.

- The community being fostered is incredible. This is also partly made possible by the project being open source. Neo4j is currently being used in production by companies such as UBS, Cisco, Walmart, eBay, Telenor, HP, Pitney Bowes, Accenture, Lockheed Martin, Glassdoor, and many others.
The structure of the book

This book is divided into two sections:

- Section 1 (Chapter 2, Modeling Flights and Cities, to Chapter 5, Refactoring the Data Model) is essential to understand graph modeling concepts that you will use in your daily routine. We cover how to model a graph, how to query it, how to evolve a graph database to accommodate changes in the domain, and how to translate a RDBMS data model into a graph design.

- Section 2 (Chapter 6, Modeling Communication Chains, to Chapter 8, Recommendations and Analysis of Historical Data) are more reference oriented with models that you might need for optimization or for specialized cases. Topics covered are modeling chains and advantages of modeling chains, modeling access control, and designing recommendation systems based on the data present.

Summary

In this chapter, we discussed that graph databases are structures that help represent data as nodes, relationships, and properties; relationships explicitly specify and qualify the connection between two entities; labels add semantic meaning to nodes and allow for addition of indices and constraints; properties add more information to the nodes and relationships. We saw a few use cases in which graphs are used currently.

From the next chapter onward, we will delve into designing a data model and use actual Cypher queries to feed it into Neo4j. The queries used in this book are compatible with Neo4j 2.2.3. They have also been tested with Neo4j 2.3.0-M02.
Modeling Flights and Cities

We looked at what graphs are and what domains they might be suited for. Now, it is time to dive deeper into concepts that are related to graph databases and how we can go ahead and create our data in a graph. In this chapter, we will look at:

- How graphs can be used outside the social context modeling flights and cities for creating an itinerary
- Adding nodes, labels, properties, relationships, uniqueness constraints, and indices

Before we dive deep into modeling, we recommend that you download the code samples that you will need to run the examples in this chapter. The code can be downloaded from https://github.com/maheshlal2910/neo4j_graph_data_modelling.

Graphs are more than social

Often, when we talk about graph databases and their most suited use cases, people point out that social networks are a good use case for graphs. While this is true, in a way, it pigeonholes graph databases. Graph databases are versatile tools that can be used to model various domains and problems. In this book, we pick up a nonsocial example—travel, and explain how we can model data for various subsystems that would be used in a travel website using Neo4j.
Designing a system to get a travel itinerary

The travel domain is interesting in terms of data modeling challenges. Throughout this book, we will be modeling systems that work together in a website that can be used for planning flight travel. Travelers would like to look at the options for an itinerary before booking any particular set of flights, especially if there is no direct flight from the traveler's current city to the destination city. Normally, an itinerary includes total duration, layover duration, and the number of hops it takes to reach the destination. We cannot, however, derive the itinerary without modeling cities and flights, which brings us to our first data modeling problem.

Introduction to modeling flights and cities

If we were to explain the problem of cities and the number of flights between them, we could start with drawing cities as nodes. In case two cities have two or more direct flights between them, we connect those two cities with an undirected relationship, as shown in the following figure:

Figure 2.1: Cities and flight routes
In the situation depicted by Figure 2.1, there is a direct route between New York and the following cities: Chicago, Los Angeles, Washington, and Las Vegas, for instance. However, if a traveler has to fly to New York from Istanbul, they have to choose from among the following routes:

- Istanbul—London—New York
- Istanbul—Athens—Paris—New York

In Figure 2.1, an undirected relationship between cities that are connected by flights is an abstraction stating that there are at least two direct flights between those two cities. For example, between New York and Los Angeles, there should be one flight from New York to Los Angeles and vice versa. In reality, there might be multiple flights, operated by different operators, travelling to and fro between two cities that are directly connected in Figure 2.1. This complicates the problem of presenting the traveler with a good itinerary.

**Identifying the entities**

Before we jump to modeling, we need to identify the interacting entities involved in this problem. For the problem of creating an itinerary, we need cities and flights connecting them. Cities form hubs, which one can travel to or transit through. Flights fly from one city to another.

![](image)

Figure 2.2: Cities and flights
The preceding figure represents the information that is needed and applicable to both the entities. While city names aren't unique in the real world, we could use city names to uniquely identify the city in our domain. In addition to the name, a city will also have the name of the country it belongs to.

A flight can be uniquely identified by its code. Other parameters include duration of the flight (in minutes), departure and arrival time (in minutes within the day where 0000 hrs will be 0 minutes and 2359 hrs will be 1439 minutes). We capture information about the airports between which the flight operates in `source_airport_code` and `destination_airport_code`.

In the RDBMS world, an attribute that uniquely identifies a record is called a **primary key**. More often than not, this primary key attribute is denoted by prefixing `pk_` to its name. Also, primary keys are mostly some sort of long integer. In this book, we will use UUIDs as primary keys wherever other attributes can't be used as primary keys. However, in cases where we can use any property as a key, we will (for convenience) use that field as a key. Please note that in production systems, the key should be a distinct property serving a single purpose—uniquely identifying the node/relationship. Also, having either long integers or UUIDs as IDs allows us to use them in URLs where other properties might not be usable.

**Introduction to modeling nodes and relationships**

We looked at the data models in Figure 2.2. Without delving into technical details, we can say that "A person can fly from New York to London on carrier X". With this statement, we can start exploring possibilities in which this data can be modelled. A preliminary approach would be to mark cities as nodes and flights as relationships, as shown in the following figure:
Figure 2.3: A preliminary model with flights and cities—the property graph
This might seem to be a fair model, however, there are a few problems with the approach. Relationships, in graphs, are used to model how the entities' nodes are related to each other. As discussed earlier, flights are one of the two core entities in our model. Flights don't relate cities to each other, instead, they are a means to get from one city to another. Modeling flights as relationships, can work out in presenting a flight plan, but if we have to allow flight bookings in the future, then we need to change flights to nodes. In general, it's always a good practice to model any entity in the domain as a node. Figure 2.4 shows us an alternative approach to model flights and cities.

Figure 2.4: A model for flights and cities
The preceding data model has `:Flight` and `:City` as labels for the nodes for flights and cities, respectively. `:HAS_FLIGHT` and `:FLYING_TO` are relationships that link a flight to its origin city and destination city, respectively.

When we represent a part of a graph that contains all possible nodes and relationships, we lay down a specification for how data is connected and structured. Thus, we can describe graphs using specification by example.

This graph seems to be a good starting point for us to begin feeding the data into Neo4j.

Before we move forward, it would be a good idea to install Neo4j so that we can work on the Cypher queries. Neo4j can be downloaded from [http://neo4j.com/download/](http://neo4j.com/download/).

Once installed, we will use the `neo4j-shell`, a console tool for Neo4j to create nodes and relationships. Further in this book, we will make use of the Neo4j Browser tool, when we start dealing with traversal and exploring our graph. Before trying out any of the queries, ensure that the Neo4j server is started.

**Using Cypher to operate on Neo4j**

Operations on Neo4j are generally performed using a query language called Cypher. Cypher is a simple, expressive, SQL-like language that allows us to create, read, update, and delete nodes and relationships in Neo4j. To retrieve data from a Neo4j store, we write Cypher queries, which specify which nodes and which relationships to traverse.

Cypher is a declarative graph query language. Each query is built of clauses and each clause pipes/feeds the next clause with data. Cypher is designed to be a humane query language suitable for developers and operations professionals, and hence, elegantly combines simplicity, expressiveness, and efficiency.

There are ways in which you can, and should influence efficiency from a user perspective, particularly by writing queries that utilize and are sympathetic to the graph structure. However, each query is planned, costed, and executed by the query engine that tries to optimize queries. This allows users to focus on better modeling rather than worrying about the optimization of the queries being written.
Modeling Flights and Cities

To start with, we will need the following clauses:

- **CREATE**: This clause is used to create nodes and relationships.
- **MATCH**: This clause matches a certain set of nodes and relationships following the patterns specified.
- **RETURN**: This decides which part of the created data should be returned. It can be used to return nodes, relationships, or even individual properties.

Before we move forward, we need to ensure that we have a working Neo4j installation.

There are other tools such as Gremlin and the Java API that can be used to query and operate on Neo4j. We feel that Cypher is the most expressive among all of these options. Cypher, however, has limitations to processing which Gremlin addresses better. Gremlin, is not officially supported as of 2.2.0, and Neo4j requires a plugin to execute Cypher queries.

Creating cities in Neo4j

We will model cities as nodes, as shown in Figure 2.4, with the city's name and country as properties. Cities should have unique names. For this, we can add a constraint before we start creating cities in our graph.

The query is as follows:

```
neo4j-sh (?)$ CREATE CONSTRAINT ON (city: City) ASSERT city.name IS UNIQUE;
```

The output of the preceding query is as shown:

```
+-------------------+
| No data returned. |
+-------------------+
Constraints added: 1
```

This adds a constraint on all nodes that will henceforth be created with the label City to have a unique name property. The city in (city: City) is a placeholder, like a variable, for any node with label City. Note that the addition of a uniqueness constraint is idempotent—it can be repeated multiple times without throwing an error or changing the constraint after it first gets added.
It's a good practice to add a uniqueness constraint, like we did, before we start adding nodes that have a particular label. While a uniqueness constraint can be added anytime, creating one beforehand ensures that no two nodes with the same label will have the same identifier. Currently, there is no way to specify a uniqueness constraint that combines multiple fields. However, we can have multiple uniqueness constraints on the label. To emulate a uniqueness constraint that spans multiple properties, we can create a property that combines the values of two properties and creates a new constraint on this property with joint values. For example, if cities have unique names within the context of a country, we can create a property with the city name and country name appended and create a uniqueness constraint on that.

The primary function of a label is to provide semantic context for nodes. As discussed earlier, a node can have multiple labels, because a node can represent multiple things to the same system. As a corollary, a node can have multiple uniqueness constraints applied to it in context of the different labels applied to it. Labels can be added or removed from a node. While allowing for uniqueness constraints isn't the primary role of labels, it is important to note that without labels, adding uniqueness constraints isn't possible.

We can add our first city—New York as shown here:

```bash
neo4j-sh (?)$ CREATE (city:City{name:"New York",
country:"United States of America"}) RETURN n;
```

The output is as follows:

```
+-------------------------------------------------------------+
| n                                                           |
| +-------------------------------------------------------------+  
| Node[1]{name:"New York",country:"United States of America"} |
+-------------------------------------------------------------+
```

In the query, `city` is a variable name just like `n` or `x`. While it can be anything, we recommend usage of readable and meaningful variable names in the query. We use variable names to ensure that we are referring to the same set of nodes, to use them in multiple parts of the query.

---

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Modeling Flights and Cities

The output of each query on the Neo4j console can be divided into three parts:

- **Variable name**: This is the name of the value that is returned by the query.
- **Variable values**: These are the values that are returned by the query.
- **Modification summary**: This includes how much data is returned, everything that was (or not) modified, and the time taken to run the query.

The ID of the node created, is a part of the output, but should never be used to identify the node uniquely. Neo4j recycles IDs of any nodes that have been deleted. For example, if we delete the node we just created, the ID (1) of the node will be added to the free pool, and next time the server restarts, it might be reassigned to some other node we might create. Thus, using the generated Neo4j ID to identify a node is risky.

We can also create multiple cities in the same query with the following code:

```sql
neo4j-sh (?)$ CREATE
 (:City{name:"Mumbai", country:"India"}),
 (:City{name:"Chicago", country:"United States of America"}),
 (:City{name:"Las Vegas", country:"United States of America"}),
 (:City{name:"Los Angeles", country:"United States of America"}),
 (:City{name:"Toronto", country:"Canada"}),
 (:City{name:"London", country:"United Kingdom"}),
 (:City{name:"Madrid", country:"Spain"}),
 (:City{name:"Paris", country:"France"}),
 (:City{name:"Athens", country:"Greece"}),
 (:City{name:"Rome", country:"Italy"}),
 (:City{name:"Istanbul", country:"Turkey"}),
 (:City{name:"Singapore", country:"Singapore"}),
 (:City{name:"Sydney", country:"Australia"}),
 (:City{name:"Melbourne", country:"Australia"});
```

The output of the previous query is as follows:

```
+-------------------+
| No data returned. |
+-------------------+
Nodes created: 14
Properties set: 28
Labels added: 14
```
We can retrieve the cities we just created by using the following query:

```bash
neo4j-sh (?)$ MATCH (city:City{name:"New York"}) RETURN city;
```

The output of this query is as follows:

```
+-------------------------------------------------------------+
| city                                                        |
| Node[1]{country:"United States of America",name:"New York"} |
+-------------------------------------------------------------+
1 row
```

We can also retrieve multiple cities in the same query as shown here:

```bash
neo4j-sh (?)$ MATCH (c1:City{name:"Athens"}),
                  (c2:City{name:"Mumbai"}) RETURN c1, c2;
```

The output is as follows:

```
+-----------------------------------------------------------+
| c1                          | c2                          |
| Node[7]{name:"Athens",country:"Greece"}                   |
| Node[9]{name:"Mumbai",country:"India"}                    |
+------------------------------ ----------------------------+
1 row
```

While we can return whole nodes as our result, it's generally advised to return only the data that is needed. It's also possible to alias the data that is returned. The following query returns the names of two cities as shown:

```bash
neo4j-sh (?)$ MATCH (c1:City{name:"Athens"}),
                  (c2:City{name:"Mumbai"}) RETURN c1.name as first_city, c2.name as second_city;
```

The output is as follows:

```
+--------------------------+
| first_city | second_city |
+--------------------------+
| "Athens"   | "Mumbai"    |
+--------------------------+
1 row
```
Indices

We have added a property `country` to every node labeled as `City`. We can search for cities belonging to a country as well. Searching without indexes is inefficient, and hence, it's a good practice to add an index for properties which we anticipate the nodes will be searched by. Let's see how this is done using an example as shown:

```
neo4j-sh (?)$ CREATE INDEX ON :City(country);
```

The output is as follows:

```
+-------------------+
| No data returned. |
+-------------------+
Indexes added: 1
```

Creating an index returns `Indexes added: 1`. However, at this point, an index may not have been added—but will be created. In our database, an index would already have been created. In larger datasets, the indexing will take time.

The index we have just created is called `schema index`.

Whenever we send Neo4j a Cypher query for execution, Neo4j will try reducing the queried graph to a small subgraph, and then try comparing which nodes have `properties:value` queried. In larger databases, the subgraph itself might have millions of nodes, and checking each node within the subgraph for the presence of the `property:value` pair would be time consuming. To avoid store scans, and to improve discrete lookup performance, we can declare an index on properties for a given label. It is also a good practice to restrict the subgraph using the label of the nodes we want the query to operate on. Since labels are indexed by default, finding nodes using labels is fast for Neo4j.

We can now search for cities in a country without worrying about performance. For example, to search all cities in the United States of America we will use the following query:

```
neo4j-sh (?)$ MATCH (c:City{country:"United States of America"}) RETURN c.name as City;
```
Adding flights to Neo4j

Since we have identified flights as entities, we will create them as nodes. To begin with, we should create a uniqueness constraint on the property code for the label :Flight as shown:

```
neo4j-sh (?)$ CREATE CONSTRAINT ON (flight:Flight)
    ASSERT flight.code IS UNIQUE;
```

The output is as follows:

```
+-------------------+
| No data returned. |
| Constraints added: 1 |
```

We can create a flight with its information as a standalone entity:

```
neo4j-sh (?)$ CREATE (flight:Flight {code:"AA9",
    carrier:"American Airlines", duration:314,
    source_airport_code:"JFK", departure:1300,
    destination_airport_code:"LAX", arrival:114})
RETURN flight.code as flight_code,
    flight.carrier as carrier, flight.source_airport_code
as from, flight.destination_airport_code as to;
```
Modeling Flights and Cities

The output is as follows:

<table>
<thead>
<tr>
<th>flight_code</th>
<th>carrier</th>
<th>from</th>
<th>to</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;AA9&quot;</td>
<td>&quot;American Airlines&quot;</td>
<td>&quot;JFK&quot;</td>
<td>&quot;LAX&quot;</td>
</tr>
</tbody>
</table>

1 row
Nodes created: 1
Properties set: 5
Labels added: 1

This flight can now be connected to the source and destination cities by means of relationships. Relationships in Neo4j must have a direction while being created. In the absence of a specified direction while creation, the query will throw an error. Here's an example:

```cypher
MATCH (source:City {name:"New York"}),
      (destination:City {name:"Los Angeles"}),
      (flight:Flight{code:"AA9"})
CREATE (source)-[:HAS_FLIGHT]->(flight)-[:FLYING_TO]-(destination);
```

The output of this query is as follows:

WARNING: Only directed relationships are supported in CREATE (line 1, column 164 (offset: 163))

"MATCH (source:City {name:"New York"}),
      (destination:City {name:"Los Angeles"}),
      (flight:Flight{code:"AA9"})CREATE (source)-[:HAS_FLIGHT]
     ->(flight)-[:FLYING_TO]-(destination)"

In the preceding example, we don't have a direction specified on the [:FLYING_TO] relationship.

If we provide a direction to the relationship in the Cypher query, Neo4j will create the relationship in the database.

Input the following query:

```cypher
MATCH (source:City {name:"New York"}),
      (destination:City {name:"Los Angeles"}),
      (flight:Flight{code:"AA9"})CREATE (source)-[:HAS_FLIGHT]
     ->(flight)-[:FLYING_TO]-(destination);
```
The output obtained is as follows:

```
| No data returned. |
+-------------------+
Relationships created: 2
Properties set: 2
```

The structure of the query is simple. We select the nodes that need to be linked and then create a relationship between them. In the preceding example, source, destination and flight represent variables that are temporarily used to hold the nodes between which the relationships have to be formed. :HAS_FLIGHT and :FLYING_TO are both relationship types. As discussed earlier, relationships can have properties.

The type of a relationship is tied to the relationship. They are like labels in the semantic sense, but once a relationship is created with a type, it cannot be changed, nor can more types be added. The direction of the relationship is denoted by the direction in which the arrow (->) points. Both the direction and type are intrinsic to the relationship, and to change any of these, we need to delete the relationship and recreate it with the desired type and direction.

These two steps of creating the flight and then connecting them to the cities can be condensed into one by writing a slightly longer query, as shown here:

```
neo4j-sh (?)$ CREATE (flight:Flight {code:"AA920",
carrier:"American Airlines", duration:305,
source_airport_code:"LAX", departure:505,
destination_airport_code:"JFK", arrival:990})
WITH flight
MATCH (source:City {name:"Los Angeles"}),
    (destination:City {name:"New York"})
CREATE (source)-[:HAS_FLIGHT]->(flight)-[:FLYING_TO]->(destination);
```

The output of this query is as follows:

```
| No data returned. |
+-------------------+
Nodes created: 1
Relationships created: 2
Properties set: 7
Labels added: 1
```
In the preceding query, we used `WITH` to pipe the result of the first part of the query to the second.

Let's create a few more flights using the queries in `flights.cqy`, which we downloaded at the beginning of this chapter.

**Traversing relationships**

Traversing relationships in Neo4j is done by specifying the path that we want to be matched. Queries can be open ended, like the one here, in which we haven’t highlighted the direction in which we want the relationship to be traversed. Other open-ended queries might refrain from specifying the relationship type to be traversed or the node labels that would identify the subgraph that needs to be traversed.

Input the following query:

```
neo4j-sh (?)$ MATCH (source:City {name:"Los Angeles"})
  ->[:HAS_FLIGHT]-(f:Flight)-[:FLYING_TO]->
  (destination:City {name:"New York"})
RETURN f.code as flight_code, f.carrier as carrier;
```

The output of this query is as follows:

```
+-----------------------------------+
| flight_code | carrier             |
|----------------+------------------|
| "UA1262"      | "United"         |
| "AA920"       | "American Airlines" |
+-----------------------------------+
2 rows
```

**Summary**

In this chapter, you learned that graphs can be described by describing a subgraph that contains all possible relationships, nodes, and properties; this is called specification by example. You also learned that entities should be modeled as nodes, and relationships must be used to denote semantic correlation between two entities. Nodes can have multiple labels, while relationships can have only one type. We also discussed the advantages of using labels apart from the semantic context they provide.
Formulating an Itinerary

In the previous chapter, you learned to visualize a domain as a graph and how to feed it into Neo4j using Cypher. This chapter will revolve around using that data to get the desired information. This can be done using Cypher to query the graph and return the desired data. You will learn the following:

- Querying using Cypher for variable length relationships
- Using functions to extract data from a collection of nodes
- What operations are suited for Cypher

Creating an itinerary from flights and cities

We modelled cities and flights in the previous chapter. In this chapter, our primary focus will be on creating an itinerary from the graph we have. A few considerations while we are fetching the itinerary are as follows:

- Even if there is no direct flight from city A to city B, most people are comfortable with two or less stopovers/changes of flights
- If there is a change of flights or stopover involved, the stopover should be at least for two hours so that the travelers can change flights in spite of any unforeseen delays
Information and paths

In a graph, we discover information by traversing the nodes and relationships from some starting node or nodes. Collectively, the start node, the end node, the relationships, and intermediate nodes together consist of a path. We define the path using the node labels and relationship types. Writing queries with node labels and relationship types allows the query to be expressive.

Using Cypher to find a path

In order to find flights, we can use the clauses that we used in the previous chapter. In addition to the match and return clause, we will use the with clause and collection functions. A short description of each of these is as follows:

- The match clause is used to match a path having the specified node and relationship types.
- The return clause is used to return the matched path, a few nodes/relationships, or properties from nodes/relationships in the path.
- Collection functions are used to extract data from a collection of nodes that the match clause or other collection functions return.
- The with clause is used to pipe the results from one logical part of the query to another logical part. It can be combined with usage of.

We already wrote a query to find flights between two cities.

```cypher
CALL

MATCH

IF

RETURN

WITH

WHERE

ORDER BY

LIMIT

RETURN
```

The query to find a flight path is a simple extension of the query to find one flight.

To visualize paths, we are going to use the Neo4j browser. It is a better tool compared to the neo4j-shell to visualize connected data. For queries where we return a couple of properties, the neo4j-shell is still a tool of choice.
The query to be written is:

```
MATCH path = (london:City{name:'London'})-[[:HAS_FLIGHT|FLYING_TO]*0..6]->(melbourne:City{name:'Melbourne'}) RETURN path;
```

The following screenshot shows you the output of the preceding query:

![Figure. 3.1: Flights from London to Melbourne](image)

If we compare this with the query to find a flight between New York and London, you will notice that we have eliminated the mention of the flight node, and instead specified a pattern of relationships to match. The pipe symbol (|) separating the relationship types is used to specify multiple relationships that might be matched by the query. The asterisk (*) and the range after it specify the relationship-node hops the query should be traversing.
In cases where the graph has cycles, usage of * along with the specification of the depth should be carefully thought out. A carefully thought out query with both lower bound and upper bound of the traversal will return useful data, while a query that has been hacked together without much thought might not return any data. In some cases, if the query runs into a cycle and has no upper bound for the query depth, the JVM might crash.

We have specified six as the maximum number of hops to be taken. This number is the result of an assumption made earlier in this chapter; most people would be comfortable with at the most two stopovers. This translates to at most three flight changes. Considering each flight has two relationships connecting it to a source and destination city, we have to traverse at the most six hops in order to get our itinerary.

It is good practice to just return the information needed for further processing rather than returning the whole path from Neo4j.

The input query is as shown here:

```sql
MATCH path = (london:City{name:'London'})-[;HAS_FLIGHT|FLYING_TO*0..6]->(melbourne:City{name:'Melbourne'})
WITH
FILTER(f in nodes(path) WHERE "Flight" IN labels(f)) as flights,
FILTER(city in nodes(path) WHERE "City" IN labels(city)) as cities
RETURN
EXTRACT(city IN cities| city.name) as city,
EXTRACT (flight IN flights| flight.code) as code,
EXTRACT (flight IN flights| flight.carrier) as carrier,
EXTRACT (flight IN flights| flight.departure) as departure,
EXTRACT (flight IN flights| flight.arrival) as arrival,
EXTRACT (flight IN flights| flight.duration) as duration,
EXTRACT (flight IN flights| flight.source_airport_code) as from_airport,
EXTRACT (flight IN flights| flight.destination_airport_code) as to_airport
```
Figure 3.2: Information of flights from London to Melbourne

**Business logic should lie in code**

We returned data from Neo4j without any processing such as ordering flights by their duration or only choosing those connecting flights that are flying out at least two hours after the arrival of the incoming flight. There are multiple reasons for this:

- Returning flights or itineraries sorted by flight duration doesn't solve anything for us since the total journey time will be a sum of all the flight durations and all the layovers.
- Eager aggregation is generally an expensive process and, in case the client consuming data from Neo4j has processing power, it's better to delegate the processing to the client rather than do it in Neo4j.
- In our case specifically, the aggregation for layover times is a complex calculation, more suited to programming languages rather than a query language such as Cypher.
- The minimum layover time of two hours is more of a business logic and needs to be tackled in code and not on the database. In general, it's better to keep queries and business logic separate.
Summary
In this chapter, you learned how to query multiple hop paths and set limits of hops that we have to traverse. You also learned to use functions to extract data from a set of collections. In the next chapter, you will learn how to redesign the existing data.
In the previous chapters, you learned how to model flights, reviews, comments, and users. We used a graph to find routes between two cities. However, we limited ourselves to problems that naturally fit into a graph, that is, routing. In this chapter, we will explore how graphs can be used to solve problems that are dominantly solved using RDBMS, for example, bookings.

We will discuss the following topics in this chapter:

- Modeling bookings in an RDBMS
- Modeling bookings in a graph
- Adding bookings to graphs
- Using Cypher to find bookings and journeys
Building a data model for booking flights

We have a graph that allows people to search flights. At this point, a logical extension to the problem statement could be to allow users to book flights online after they decide the route on which they wish to travel. We were only concerned with flights and the cities. However, we need to tweak the model to include users, bookings, dates, and capacity of the flight in order to make bookings. Most teams choose to use an RDBMS for sensitive data such as user information and bookings. Let's understand how we can translate a model from an RDBMS to a graph.

A flight booking generally has many moving parts. While it would be great to model all of the parts of a flight booking, a smaller subset would be more feasible, to demonstrate how to model data that is normally stored in a RDBMS.

A flight booking will contain information about the user who booked it along with the date of booking. It's not uncommon to change multiple flights to get from one city to another. We can call these journey legs or journeys, and model them separately from the booking that has these journeys. It is also possible that the person booking the flight might be booking for some other people. Because of this, it is advisable to model passengers with their basic details separately from the user.

We have intentionally skipped details such as payment and costs in order to keep the model simple.

A simple model of the bookings ecosystem

A booking generally contains information such as the date of booking, the user who booked it, and a date of commencement of the travel. A journey contains information about the flight code. Other information about the journey such as the departure and arrival time, and the source and destination cities can be evaluated on the basis of the flight which the journey is being undertaken. Both booking and journey will have their own specific IDs to identify them uniquely. Passenger information related to the booking must have the name of the passengers at the very least, but more commonly will have more information such as the age, gender, and e-mail.
A rough model of the **Booking**, **Journey**, **Passenger**, and **User** looks like this:

![Diagram](image)

**Figure 4.1: Bookings ecosystem**

### Modeling bookings in an RDBMS

To model data shown in *Figure 4.1* in an RDBMS, we will have to create tables for bookings, journeys, passengers, and users. In the previous model, we have intentionally added `booking_id` to **Journeys** and `user_id` to **Bookings**. In an RDBMS, these will be used as foreign keys.

We also need an additional table `Bookings_Passengers_Relationships` so that we can depict the many relationships between Bookings and Passengers. The multiple relationships between Bookings and Passengers help us to ensure that we capture passenger details for two purposes. The first is that a user can have a master list of travelers they have travelled with and the second use is to ensure that all the journeys taken by a person can be fetched when the passenger logs into their account or creates an account in the future.
We are naming the foreign key references with a prefix `fk_` in adherence to the popular convention.

![Diagram of RDBMS with foreign key references](image-url)

**Figure 4.2: Modeling bookings in an RDBMS**
In an RDBMS, every record is a representation of an entity (or a relationship in cases of relationship tables). In our case, we tried to represent a single booking record as a single block. This applies to all other entities in the system, such as the journeys, passengers, users, and flights. Each of the records has its own ID by which it can be uniquely identified. The properties starting with `fk_` are foreign keys, which should be present in the tables to which the key points.

In our model, passengers may or may not be the users of our application. Hence, we don’t add a foreign key constraint to the **Passengers** table. To infer whether the passenger is one of the users or not, we will have to use other means of inferences, for example, the e-mail ID. Given the relationships of the data, which are inferred using the foreign key relationships and other indirect means, we can draw the logical graph of bookings as shown in the following diagram:
Figure 4.3 shows us the logical graph of how entities are connected in our domain. We can translate this into a **Bookings** subgraph. In Chapter 2, *Modeling Flights and Cities*, we briefly touched upon specification by example. From the related entities of Figure 4.3, we can create a specification of the **Bookings** subgraph, which is as follows:

![Diagram of subgraph of bookings](image)

Comparing *Figure 5.3* and *Figure 5.4*, we observe that all the $fk_\_\_\_$ properties are removed from the nodes that represent the entities. Since we have explicit relationships that can now be used to traverse the graph, we don't need implicit relationships that rely on foreign keys to be enforced. We put the date of booking on the booking itself rather than on the relationship between **User** and **Bookings**.
The date of booking can be captured either in the booking node or in the :MADE_BOOKING relationship. The advantage of capturing it in the booking node is that we can further run queries efficiently on it rather than relying on crude filtering methods to extract information from the subgraph.

An important addition to the Bookings object is adding the properties year, month, and day. Since date is not a datatype supported by Neo4j, range queries become difficult. Timestamps solve this problem to some extent, for example, if we want to find all bookings made between June 01, 2015 and July 01, 2015, we can convert them into timestamps and search for all bookings that have timestamps between these two timestamps. This, however, is a very expensive process, and would need a store scan of bookings. To alleviate these problems, we can capture the year, day, and month on the booking.

While adapting to the changing needs of the system, remodeling the data model is encouraged. It is also important that we build a data model with enough data captured for our needs—both current and future. It is a judgment-based decision, without any correct answer. As long as the data might be easily derived from existing data in the node, we recommend not to add it until needed. In this case, converting a timestamp to its corresponding date with its components might require additional programming effort. To avoid that, we can begin capturing the data right away. There might be other cases, for example, we want to introduce a property Name on a node with First name and Last name as properties. The derivation of Name from First name and Last name is straightforward. In this case, we advise not to capture the data till the need arises.

Creating bookings and users in Neo4j

For bookings to exist, we should create users in our data model.

As with earlier chapters, please download the queries from the downloadable code bundle available with this book. Alternatively, the queries can also be downloaded from https://github.com/maheshlal2910/neo4j_graph_data_modelling.
Creating users

To create users, we create a constraint on the e-mail of the user, which we will use as an unique identifier as shown in the following query:

```
neo4j-sh (?)$ CREATE CONSTRAINT ON (user:User)
    ASSERT user.email IS UNIQUE;
```

The output of the preceding query is as follows:

```
+-------------------+
| No data returned. |
+-------------------+
Constraints added: 1
```

With the constraint added, let's create a few users in our system:

```
neo4j-sh (?)$ CREATE (:User{name:"Mahesh Lal",
    email:"mahesh.lal@gmail.com"}),
    (:User{name:"John Doe", email:"john.doe@gmail.com"}),
    (:User{name:"Vishal P", email:"vishal.p@gmail.com"}),
    (:User{name:"Dave Coeburg", email:"dave.coeburg@gmail.com"}),
    (:User{name:"Brian Heritage",
    email:"brian.heritage@hotmail.com"}),
    (:User{name:"Amit Kumar", email:"amit.kumar@hotmail.com"}),
    (:User{name:"Pramod Bansal",
    email:"pramod.bansal@hotmail.com"}),
    (:User{name:"Deepali T", email:"deepali.t@gmail.com"}),
    (:User{name:"Hari Seldon", email:"hari.seldon@gmail.com"}),
    (:User{name:"Elijah", email:"elijah.b@gmail.com"});
```

The output of the preceding query is as follows:

```
+-------------------+
| No data returned. |
+-------------------+
Nodes created: 10
Properties set: 20
Labels added: 10
```

Please add more users from users.cqy.
Creating bookings in Neo4j

As discussed earlier, a booking has multiple journey legs, and a booking is only complete when all its journey legs are booked.

Bookings in our application aren’t a single standalone entity. They involve multiple journeys and passengers. To create a booking, we need to ensure that journeys are created and information about passengers is captured. This results in a multistep process.

To ensure that booking IDs remain unique and no two nodes have the same ID, we should add a constraint on the \texttt{id} property of booking:

```bash
neo4j-sh (?)$ CREATE CONSTRAINT ON (b:Booking)
  ASSERT b.id IS UNIQUE;
```

The output will be as follows:

```
+-------------------+
| No data returned. |
+-------------------+
Constraints added: 1
```

We will create similar constraints for \texttt{Journey} as shown here:

```bash
neo4j-sh (?)$ CREATE CONSTRAINT ON (journey:Journey)
  ASSERT journey._id IS UNIQUE;
```

The output is as follows:

```
+-------------------+
| No data returned. |
+-------------------+
Constraints added: 1
```

Add a constraint for the e-mail of passengers to be unique, as shown here:

```bash
neo4j-sh (?)$ CREATE CONSTRAINT ON (p:Passenger)
  ASSERT p.email IS UNIQUE;
```

The output is as shown:

```
+-------------------+
| No data returned. |
+-------------------+
Constraints added: 1
```
Modeling Bookings and Users

With constraint creation, we can now focus on how bookings can be created. We will be running this query in the Neo4j browser, as shown:

```cypher
MATCH (user:User{email:"john.doe@gmail.com"})
MATCH (f1:Flight{code:"VS9"}), (f2:Flight{code:"AA9"})

//Create a booking for a date
MERGE (user)-[m:MADE_BOOKING]->(booking:Booking
    {_id:"0f64711c-7e22-11e4-a1af-14109fda6b71", booking_date:1417790677.274862, year: 2014, month: 12, day: 5})

//Create or get passengers
MERGE (p1:Passenger{email:"vishal.p@gmail.com"}) ON CREATE SET p1.name = "Vishal Punyani", p1.age= 30
MERGE (p2:Passenger{email:"john.doe@gmail.com"}) ON CREATE SET p2.name = "John Doe", p2.age= 25

//Create journeys to be taken by flights
MERGE (j1:Journey{_
    _id:"712785b8-1aff-11e5-1ab4-6c40089a9424", date_of_journey:1422210600.0, year:2015, month: 1, day: 26})-[[:BY_FLIGHT]]->
    (f1)
MERGE (j2:Journey{_
    _id:"843de08c-1aff-11e5-8643-6c40089a9424", date_of_journey:1422210600.0, year:2015, month: 1, day: 26})-[[:BY_FLIGHT]]->
    (f2)

WITH user, booking, j1, j2, f1, f2, p1, p2

//Merge journeys and booking, Create and Merge passengers with bookings, and return data
MERGE (booking)-[:HAS_PASSENGER]->(p1)
MERGE (booking)-[:HAS_PASSENGER]->(p2)
MERGE (booking)-[:HAS_JOURNEY]->(j1)
MERGE (booking)-[:HAS_JOURNEY]->(j2)
RETURN user, p1, p2, j1, j2, f1, f2, booking
```

The output is as shown in the following screenshot:
We have added comments to the query to explain the different parts of the query. The query can be divided into the following parts:

- Finding flights and user
- Creating bookings
- Creating journeys
- Creating passengers and link to booking
- Linking journey to booking
We have the same start date for both journeys, but in general, the start dates of journeys in the same booking will differ if:

- The traveler is flying across time zones. For example, if a traveler is flying from New York to Istanbul, the journeys from New York to London and from London to Istanbul will be on different dates.
- The traveler is booking multiple journeys in which they will be spending some time at a destination.

Let's use `bookings.cqy` to add a few more bookings to the graph. We will use them to run further queries.

### Queries to find journeys and bookings

With the data on bookings added in, we can now explore some interesting queries that can help us.

#### Finding all journeys of a user

All journeys that a user has undertaken will be all journeys that they have been a passenger on. We can use the user's e-mail to search for journeys on which the user has been a passenger.

To find all the journeys that the user has been a passenger on, we should find the journeys via the bookings, and then using the bookings, we can find the journeys, flights, and cities as shown:

```sql
neo4j-sh (?)$ MATCH (b:Booking)-[:HAS_PASSENGER]->(p:Passenger{email: "vishal.p@gmail.com"})
WITH b
MATCH (b)-[:HAS_JOURNEY]->(j:Journey)-[:BY_FLIGHT]->(f:Flight)
WITH b._id as booking_id, j.date_of_journey as date_of_journey,
COLLECT(f) as flights ORDER BY date_of_journey DESC
MATCH (source:City)-[:HAS_FLIGHT]->(f)-[:FLYING_TO]-(destination:City)
WHERE f in flights
RETURN booking_id, date_of_journey, source.name as from, f.code as by_flight, destination.name as to;
```
While this query is useful to get all the journeys of the user, it can also be used to map all the locations the user has travelled to.

### Queries to find the booking history of a user

The query for finding all bookings by a user is straightforward, as shown here:

```bash
$neo4j-sh (?)$ MATCH (user:User{email:"mahesh.lal@gmail.com"})-[:MADE_BOOKING]->(b:Booking) RETURN b._id as booking_id;
```

The output of the preceding query is as follows:

<table>
<thead>
<tr>
<th>booking_id</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;251679be-1b3f-11e5-820e-6c40089a9424&quot;</td>
</tr>
<tr>
<td>&quot;ff3dd694-7e7f-11e4-bb93-14109fda6b71&quot;</td>
</tr>
<tr>
<td>&quot;7c63cc35-7e7f-11e4-8ffe-14109fda6b71&quot;</td>
</tr>
<tr>
<td>&quot;f5f15252-1b62-11e5-8252-6c40089a9424&quot;</td>
</tr>
<tr>
<td>&quot;d45de0c2-1b62-11e5-98a2-6c40089a9424&quot;</td>
</tr>
<tr>
<td>&quot;fef04c30-7e2d-11e4-8842-14109fda6b71&quot;</td>
</tr>
<tr>
<td>&quot;f87a515e-7e2d-11e4-b170-14109fda6b71&quot;</td>
</tr>
<tr>
<td>&quot;75b3e78c-7e2b-11e4-a162-14109fda6b71&quot;</td>
</tr>
</tbody>
</table>

8 rows
Upcoming journeys of a user

Upcoming journeys of a user is straightforward. We can construct it by simply comparing today's date to the journey date as shown:

```bash
neo4j-sh (?)$ MATCH (user:User{email:"mahesh.lal@gmail.com"})-[[:MADE_BOOKING]]-(b:Booking)-[:HAS_JOURNEY]-(j:Journey)
WHERE j.date_of_journey >=1418055307
WITH COLLECT(j) as journeys
MATCH (j:Journey)-[:BY_FLIGHT]->(f:Flight)
WHERE j in journeys
WITH j.date_of_journey as date_of_journey, COLLECT(f) as flights
MATCH (source:City)-[:HAS_FLIGHT]->(f)-[:FLYING_TO]->(destination:City)
WHERE f in flights
RETURN date_of_journey, source.name as from, f.code as by_flight, destination.name as to;
```

The output of the preceding query is as follows:

<table>
<thead>
<tr>
<th>date_of_journey</th>
<th>from</th>
<th>by_flight</th>
<th>to</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.4226426E9</td>
<td>&quot;New York&quot;</td>
<td>&quot;VS8&quot;</td>
<td>&quot;London&quot;</td>
</tr>
<tr>
<td>1.4212602E9</td>
<td>&quot;Los Angeles&quot;</td>
<td>&quot;UA1262&quot;</td>
<td>&quot;New York&quot;</td>
</tr>
<tr>
<td>1.4212602E9</td>
<td>&quot;Melbourne&quot;</td>
<td>&quot;QF94&quot;</td>
<td>&quot;Los Angeles&quot;</td>
</tr>
<tr>
<td>1.4304186E9</td>
<td>&quot;New York&quot;</td>
<td>&quot;UA1507&quot;</td>
<td>&quot;Los Angeles&quot;</td>
</tr>
<tr>
<td>1.4311962E9</td>
<td>&quot;Los Angeles&quot;</td>
<td>&quot;AA920&quot;</td>
<td>&quot;New York&quot;</td>
</tr>
</tbody>
</table>

5 rows

Summary

In this chapter, you learned how you can model a domain that has traditionally been implemented using RDBMS. We saw how tables can be changed to nodes and relationships, and we explored what happened to relationship tables. You also learned about transactions in Cypher and wrote Cypher to manipulate the database. In the next chapter, you will learn about refactoring the data models.
We explored how to model cities and flights in a graph database, and are now able to run queries that return flights and routes for a journey. We also added the capability to book flights to our data model. In this chapter, we will explore how to change the data model to fit new requirements. As we go along, we will explore the following concepts:

- Modifying data model to accommodate business requirements
- Migrating the data from the old model to the new one

Capturing information about hotels at airports

While travelling, if a layover is more than six hours, travelers generally like to rest. Since the travelers might not be possessing a visa for the country that they are transiting through, most dormitories or hotels are located within the airport. As a logical next step, we can capture information about hotels at airports, so that travelers can use the information to plan their journey better. Considering there are multiple airports in a city, it is imperative to show only those hotels that are located at the airport through which the traveler is transiting.
Refactoring the Data Model

Modeling airports and hotels

To be able to show only those hotels that are located at the airport through which the traveler is transiting, we need to model airports. Currently, airports are a part of the flight information, and this needs to change. We will extract airport information (that is, airport_code) into a separate node labeled :Airport, as shown in Figure 5.1. The property code will act as a unique identifier for an airport.

Hotels will be modeled with their name and the price. Since prices should be comparable, storing them as a number would be beneficial. Considering hotel chains have similar or same names for each class of hotel that they own, it would be good to have an ID on the hotels.

The currency in which the price is expressed should be a application concern and should not be spread across data and application. Ideally, a standard currency (for example, USD or EUR) would be used to express the price, and the conversion to local currency of the buyer/visitor should be applied in real time depending on the daily market rates.

Figure 5.1: Airports and hotels

Hotels will be modeled with their name and the price. Since prices should be comparable, storing them as a number would be beneficial. Considering hotel chains have similar or same names for each class of hotel that they own, it would be good to have an ID on the hotels.

The currency in which the price is expressed should be a application concern and should not be spread across data and application. Ideally, a standard currency (for example, USD or EUR) would be used to express the price, and the conversion to local currency of the buyer/visitor should be applied in real time depending on the daily market rates.
The following figure shows a subgraph, which specifies the structure of hotels, airports, and cities:

Figure 5.2: Airports and hotels subgraph
Extracting airport information from flights

There are multiple steps involved in making the successful transition from airports being properties of flights to airports being an entity connected to the city they are located in.

To start with, let's create a constraint so that an airport can be uniquely identified by its code. The query is as follows:

```bash
neo4j-sh (>)$ CREATE CONSTRAINT ON (airport:Airport)
    ASSERT airport.code IS UNIQUE;
```

The output of the preceding query is as follows:

```
+-------------------+
| No data returned. |
+-------------------+
Constraints added: 1
```

Breaking airports out as a node

The next step is to break out the source_airport_code and destination_airport_code properties into nodes. After this change, the :HAS_FLIGHT and :FLYING_TO relationships will connect :Flight and :Airport rather than :Flight and :City, as shown:
In Figure 5.3, the relationships depicted with the dotted line exist currently. Relationships shown with a solid line don't exist. Since we haven't started refactoring our graph, airports don't exist. We will have to create airports and then connect the flights to the airports.
Refactoring the Data Model

We can use the following query to create airports from existing flights:

```
MATCH (source:City)-[:HAS_FLIGHT]->(f:Flight)-[:FLYING_TO]->(destination:City)
WITH source, f, destination
MERGE (source_airport:Airport{code: f.source_airport_code})
MERGE (destination_airport:Airport{code: f.destination_airport_code})
WITH source, destination, source_airport, destination_airport
MERGE (source)-[:HAS_AIRPORT]->(source_airport)
MERGE (destination)-[:HAS_AIRPORT]->(destination_airport)
RETURN source, destination, source_airport, destination_airport
```

The output of the preceding query is as shown in the following figure:

![Figure 5.4: Newly created airport nodes](image)

**Connecting flights to airports**

With the airport nodes separated, we can now connect flights to the airports, using the following code:

```
MATCH (f:Flight)
WITH f
MATCH (source_airport:Airport{code:f.source_airport_code}),
    (destination_airport:Airport{code:f.destination_airport_code})
```
WITH source_airport, destination_airport, f
MERGE (source_airport)-[:HAS_FLIGHT]->(f)-[:FLYING_TO]->(destination_airport)
RETURN source_airport, f, destination_airport

The output of the preceding code is as shown here:
Delinking flights and cities

We have now connected flights to airports, and can delink flights and cities. The following query cleans up the relationships between flights and cities, and sets the source and destination codes to null:

```
neo4j-sh (?)$ MATCH (f:Flight)-[r]-(:City)
DELETE r
SET f.source_airport_code = null, f.destination_airport_code = null;
```

The output of the preceding query is as follows:

```
+--------------------------------------------+
| No data returned                               |
+--------------------------------------------+
Set 360 properties
Deleted 180 relationships
```

Querying the refactored data model

Our data model has evolved as shown in the following diagram:

![Diagram showing flights and airports after refactoring the data model](image)

Figure 5.6: Flights and airports after refactoring the data model
With the changes in our data model, we need to change our queries to reflect the addition of airports, as shown here:

```sql
MATCH path = (london:City{name:'London'})-[:HAS_AIRPORT]->(:Airport)-[:HAS_FLIGHT|FLYING_TO*0..6]->(:Airport)
  <-[:HAS_AIRPORT]-(melbourne:City{name:'Melbourne'})
WITH
  FILTER(f in nodes(path) WHERE "Flight" IN labels(f)) as flights,
  FILTER(city in nodes(path) WHERE "City" IN labels(city)) as cities,
  FILTER(airport in nodes(path) WHERE "Airport" IN labels(airport)) as airports
RETURN
  EXTRACT(city IN cities| city.name) as city,
  EXTRACT (flight IN flights| flight.code) as code,
  EXTRACT (flight IN flights| flight.carrier) as carrier,
  EXTRACT (flight IN flights| flight.departure) as departure,
  EXTRACT (flight IN flights| flight.arrival) as arrival,
  EXTRACT (flight IN flights| flight.duration) as duration,
  EXTRACT (airport IN airports| airport.code) as airport
```

The output of the preceding code is as follows:

```
<table>
<thead>
<tr>
<th>city</th>
<th>code</th>
<th>carrier</th>
<th>departure</th>
<th>arrival</th>
<th>duration</th>
<th>airport</th>
</tr>
</thead>
<tbody>
<tr>
<td>London, Melbourne</td>
<td>[KAY, 119, 120, 121]</td>
<td>American Airlines, American Airlines, American Airlines</td>
<td>[200, 120, 130]</td>
<td>[120, 111, 111]</td>
<td>[200, 350, 450]</td>
<td>JFK, JPB, LAX, NBO</td>
</tr>
<tr>
<td>London, Melbourne</td>
<td>[SAS, 123, 124]</td>
<td>Virgin Atlantic, American Airlines, American Airlines</td>
<td>[200, 120, 130]</td>
<td>[120, 111, 111]</td>
<td>[200, 350, 450]</td>
<td>JFK, JPB, LAX, NBO</td>
</tr>
<tr>
<td>London, Melbourne</td>
<td>[KLM, 125, 126, 127]</td>
<td>American Airlines, United, American Airlines</td>
<td>[200, 120, 130]</td>
<td>[120, 111, 111]</td>
<td>[200, 350, 450]</td>
<td>JFK, JPB, LAX, NBO</td>
</tr>
<tr>
<td>London, Melbourne</td>
<td>[QF, 128, 129]</td>
<td>Virgin Atlantic, United, American Airlines</td>
<td>[200, 120, 130]</td>
<td>[120, 111, 111]</td>
<td>[200, 350, 450]</td>
<td>JFK, JPB, LAX, NBO</td>
</tr>
<tr>
<td>London, Melbourne</td>
<td>[AA, 130, 131]</td>
<td>American Airlines, American Airlines, United Airlines</td>
<td>[200, 120, 130]</td>
<td>[120, 111, 111]</td>
<td>[200, 350, 450]</td>
<td>JFK, JPB, LAX, NBO</td>
</tr>
<tr>
<td>London, Melbourne</td>
<td>[LH, 132, 133]</td>
<td>Virgin Atlantic, United, American Airlines</td>
<td>[200, 120, 130]</td>
<td>[120, 111, 111]</td>
<td>[200, 350, 450]</td>
<td>JFK, JPB, LAX, NBO</td>
</tr>
<tr>
<td>London, Melbourne</td>
<td>[AIR, 137, 138]</td>
<td>Virgin Atlantic, United Airlines, American Airlines</td>
<td>[200, 120, 130]</td>
<td>[120, 111, 111]</td>
<td>[200, 350, 450]</td>
<td>JFK, JPB, LAX, NBO</td>
</tr>
</tbody>
</table>
```

Given our new model, the output format differs slightly. However, the data returned is the same as our last itinerary query in Chapter 3, Formulating an Itinerary.
Reasons for not migrating using a single query

Evolution is a constant in the software industry. Most of the times migrations are done, the database and code changes are simultaneous and all of this is deployed in a big bang release. An example of a big bang release in our case would be to make the constraint, make data changes, and delete the relationships in one go. This change will need the code to be deployed along with the changes to the database so that the applications keep running. There are multiple downsides to this approach:

- If something goes wrong at the database end, there might be an outage. A rollback of code will be required along with restoring the database to an earlier state.
- This is more time consuming since it will require a lot more testing and preparation than smaller increments, which can be leak proofed.

If we separate the migration into two steps—constraint and path creation, and relationship removal—we gain the following advantages:

- Since constraint and path creation is done in the first step, we need not deploy the code that has been changed to use the new path at the same time. We can wait and test it further, buying us enough time. Once we are confident about code changes we have made and have released the code to production, we can run the script to remove the relationships that previously represented flights.
- Given that there are no deletions in the first script, anything going wrong won’t affect the stability of the application. The cause can be investigated without any downtime.
- Since the deletions in the second script won’t affect the subgraph that will be in use by the application, any unfortunate errors won’t result in application downtime.

Adding hotels to airports

Now that we have airports as nodes, we can add hotels to our data model. As discussed earlier, hotels have an ID, name, and average price.

Let’s start by adding a constraint on the ID of the hotel, which is the _id property, as shown:

    neo4j-sh (?)$ CREATE CONSTRAINT ON (hotel:Hotel) ASSERT hotel._id IS UNIQUE;
The output of the preceding query is as shown:

| No data returned. |

Constraints added: 1

We can add a hotel and connect it to the JFK airport using the following query:

```
neo4j-sh (?)$ CREATE (hotel:Hotel {_id:"6ad8ce6e-1c0e-11e5-8db1-6c40089a9424", name:"Hilton", price: 180})
WITH hotel
MATCH (airport:Airport{code:"JFK"})
WITH airport, hotel
MERGE (airport)-[:HAS_HOTEL]->(hotel)
RETURN airport, hotel;
```

The output of the preceding query is as follows:

![Graph showing the connection between JFK airport and Hilton hotel](image)

Figure 5.8: Airport hotels

![Alt Text: We can add more hotels from the hotels.cqy file that can be downloaded along with the code for this chapter.](image)
Refactoring the Data Model

**Fetching hotels**

Hotels can be found on the basis of which airport are they connected to, as shown in the following query:

```
neo4j-sh (>)$ MATCH (airport:Airport)-[:HAS_HOTEL]->(hotel:Hotel)
WHERE airport.code IN ['JFK', 'LAX']
RETURN airport.code, hotel.name, hotel.price;
```

The output of the preceding query is as follows:

```
+-----------------------------------------------------+
| airport.code | hotel.name             | hotel.price |
|----------------+------------------------+------------|
| "JFK"          | "Hampton Inn"          | 70         |
| "JFK"          | "Fairfield Inn"        | 80         |
| "LAX"          | "LAX South Travelodge" | 93         |
| "LAX"          | "Sheraton"             | 170        |
| "LAX"          | "Concourse"            | 100        |
+-----------------------------------------------------+
5 rows
```

Although we can find hotels while searching for flights, it is not necessary. Once the flights have been selected, this is an additional step that gives the travelers some information.

**Summary**

In this chapter, we explored how we can evolve a graph database in two ways: changing design wherever necessary and adding more varied data.

Adding more varied data should always be for business reasons. Re-design of data might be done for optimizations or could be driven by business reasons. Either of the evolutions are simple to carry out in graph databases like Neo4j, and if planned properly, there is no outage required.

In the next chapter, we will learn about modeling communication chains.
In the previous chapters, we explored designing a graph that allows a traveler to choose a route of travel, book flights, and also view information about the hotels they might stay at in case they have a long layover. In this chapter, we will explore how can we model reviews for the airport hotels that we introduced in Chapter 5, Refactoring the Data Model.

In this chapter, we will explore the following modeling reviews:

- Modeling comments on reviews as chains
- Considerations for modeling temporal data as chains

Capturing traveler reviews for hotels

Currently, among the multiple hotels at any airport, the only parameters that can help a traveler decide on a hotel are the price and the parent chain of the hotel. To compliment these parameters, we can add reviews to help travelers choose a hotel. This gives them multiple parameters to compare hotels and can thus help them choose one based on the parameters important to them. We can choose the following parameters to rate the hotels:

- Food
- Comfort
- Service
- Value for money

To add more context to the rating, we can add a review comment to the review.
There may also be scenarios where other travelers might want to ask the reviewer more questions. For these, we can add comments as separate entities on the review.

A model for reviews and comments

The following figure gives an example of the information that reviews and comments will contain:

```
:Review{
  _id: "66fca212-1e53-1e5-80f1-6c40089a9424",
  value_for_money: 4,
  comfort: 4,
  food: 3.5,
  service: 4,
  created_on: 1419877800.0,
  stayed_on: 1415903400.0
  description: "Was a pleasant stay. Though the food is average, the staff is courteous and the rooms are comfortable",
  stay_year: 2014,
  stay_month: 11,
  stay_day: 14
}

:Comment{
  _id: "c7b0061c-226b-11e5-bd5f-6c40089a9424",
  created_on: 1426098600.0,
  text: "Was the stay for less than 6 hours or more?"
}
```

Every review has to be uniquely identified for which we use the _id property. Value for money, comfort, food, and service are all the parameters that have been discussed earlier. The rating has been given on a scale of 1 to 5, assuming 1 to be lowest and 5 to be the highest. In addition to these, we have created_on, which is the timestamp of the creation of the review. Similarly, stayed_on is a timestamp of the day that the reviewer stayed at the hotel. We also capture additional information such as stay_year, stay_month, and stay_day. This will help us with range queries on the time of the year that the review was written.

Comments have _id, which uniquely identifies a comment. The created_on property is the timestamp of when the comment was created. The text is the actual communication that the traveler wants to send across to the reviewer.
In the larger ecosystem of cities, airports, hotels, and users, the reviews and comments can be modeled as follows:
Reviews are modeled as nodes and have a :FOR_HOTEL relationship with the hotel being reviewed. People comment on a review or on other comments. This can be represented by using an :ON relationship between comments and the comment/review that is being commented on. Users have a :WROTE relationship with both reviews and comments.

In our example, comments are used as communication channels between the reviewers and potential travelers. A comment may be a question seeking additional clarification or may be a response. The model doesn't consider the fact that comments might have a temporal relationship between them, for example, a comment might be a reply to another comment. The following figure is a revised design that addresses the relationship between comments:

Figure 6.3: Reviews and comments subgraph in which comments are chained
The preceding subgraph suggests that comments should be chained with a :IN_REPLY_TO relationship. Modeling comments as chains, allows to explicitly maintain an ordering between them. This way, multiple comments and responses to those comments can be maintained as separate chains. The first comment in a chain will always be :IN_REPLY_TO a review. If comments aren’t chained, then there is no way to maintain separate questions and responses to them, and it is difficult to find relevant information.

While reviews also have chronological ordering, they are better modeled as individual reviews related to hotels rather than chaining all reviews of a hotel in some particular order. Reviews are subject to a variety of sorting options, for example, reviews might be sorted by the latest written reviews or by the time of stay. There might be another possible ordering of how the reviews are displayed. Chaining them in reverse chronological order of the time created or the date of stay satisfies one use case, but makes the query for other use cases complicated.

Adding reviews to Neo4j

To add reviews to Neo4j, we should first create an uniqueness constraint on reviews, as shown:

```bash
neo4j-sh (?)$ CREATE CONSTRAINT ON (review:Review)
    ASSERT review._id IS UNIQUE;
```

The output of the preceding query is as follows:

```
| No data returned. |
+--------------------+
Constraints added: 1
```

To add a review, we can use the following query:

```bash
neo4j-sh (?)$ CREATE (review:Review{ _id: "d11f1d66-2331-11e5-ab8f-6c40089a9424",
    value_for_money: 2, comfort: 3, food: 4,
    service: 3, stayed_on: 1388670309.210871,
    created_on: 1391157765.857148, stay_year: 2014, stay_month: 1, stay_day: 2,
    description:"Was a comfortable stay. Could improve a lot though")
WITH review
```
Modeling Communication Chains

MATCH (hotel:Hotel{_id: "19397f48-1c6f-11e5-8014-6c40089a9424"}), (user:User {email: "mahesh.lal@gmail.com"})
WITH review, user, hotel MERGE (user)-[:WROTE]->(review)-[:FOR_HOTEL]->(hotel);

The output of the preceding query is as follows:

+-------------------+
| No data returned. |
+-------------------+

Nodes created: 1
Relationships created: 2
Properties set: 11
Labels added: 1

Please add more reviews from the reviews.cqy file that can be found with the code for this chapter. The code can be downloaded from the publisher's website or from https://github.com/maheshlal2910/neo4j_graph_data_modelling. The reviews.cqy file was generated using a script with randomized values, and hence doesn't have a description in each review.

Listing reviews for a hotel

The following query can be used to fetch all reviews for a hotel arranged in reverse chronological order of the reviewer's stay:

MATCH (hotel:Hotel{_id:'19397f48-1c6f-11e5-8014-6c40089a9424'})<-[:FOR_HOTEL]-(review:Review)
<-[:WROTE]-(user:User)
WITH review, user, review.stayed_on as stayed ORDER BY stayed DESC
RETURN review.value_for_money as value_for_money,
    review.comfort as comfort,
    review.food as food,
    review.service as service,
    review.stay_year as year,
    review.stay_month as month,
    review.stay_day as day,
    user.name as name;
The output of the preceding query is as follows:

<table>
<thead>
<tr>
<th>value_for_money</th>
<th>comfort</th>
<th>food</th>
<th>service</th>
<th>year</th>
<th>month</th>
<th>day</th>
<th>name</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>2015</td>
<td>6</td>
<td>18</td>
<td>Brian Heritage</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>2014</td>
<td>12</td>
<td>20</td>
<td>Aini Kumar</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>2014</td>
<td>9</td>
<td>3</td>
<td>John Doe</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>2</td>
<td>4</td>
<td>2014</td>
<td>1</td>
<td>3</td>
<td>Dave Goodburg</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>2014</td>
<td>1</td>
<td>2</td>
<td>Matthew Lit</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>1</td>
<td>4</td>
<td>2013</td>
<td>10</td>
<td>12</td>
<td>Yashri P</td>
</tr>
</tbody>
</table>

Figure 6.4: Reviews for a hotel in reverse chronological order of stay date

Using reviews to find the average rating of a hotel

Now that we have reviews for each hotel, we can get the average rating for each hotel. The following query lists all the hotels in the airports of New York in reverse order of their overall rating:

MATCH (city:City{name:"New York"})-[:HAS_AIRPORT]->(airport:Airport)-[:HAS_HOTEL]->(hotel:Hotel)
<-[:FOR_HOTEL]-(review:Review)
WITH DISTINCT hotel.name AS hotel_name,
COLLECT(review.comfort) AS comfort_ratings,
COLLECT(review.food) AS food_ratings,
COLLECT(review.service) AS service_ratings,
COLLECT(review.value_for_money) as vfm_ratings,
airport.code AS airport,
COUNT(review) as total_reviews

WITH
hotel_name,
tofloat(REDUCE(total = 0, rating in comfort_ratings | total + rating))/ total_reviews as comfort_rating,
tofloat(REDUCE(total = 0, rating in food_ratings | total + rating))/ total_reviews as food_rating,
tofloat(REDUCE(total = 0, rating in service_ratings | total + rating))/ total_reviews as service_rating,
tofloat(REDUCE(total = 0, rating in vfm_ratings | total + rating))/ total_reviews as vfm_rating,
airport,
total_reviews
RETURN airport,
    hotel_name,
    comfort_rating,
    service_rating,
    food_rating,
    vfm_rating,
    (comfort_rating + service_rating + food_rating +
    vfm_rating)/4 as overall_rating
ORDER BY overall_rating DESC

The output of the preceding query is as follows:

<table>
<thead>
<tr>
<th>airport</th>
<th>hotel_name</th>
<th>comfort_rating</th>
<th>service_rating</th>
<th>food_rating</th>
<th>vfm_rating</th>
<th>overall_rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>LGA</td>
<td>LaGuardia Plaza</td>
<td>3</td>
<td>2.5</td>
<td>3.25</td>
<td>2.25</td>
<td>2.73</td>
</tr>
<tr>
<td>JFK</td>
<td>Parkway Inn</td>
<td>2.5</td>
<td>2.8</td>
<td>2</td>
<td>3.4</td>
<td>2.7</td>
</tr>
<tr>
<td>JFK</td>
<td>Hampton Inn</td>
<td>2.333333333333333</td>
<td>2</td>
<td>2.055555555555555</td>
<td>2.56666666666666666</td>
<td>2.611111111111111</td>
</tr>
<tr>
<td>EWR</td>
<td>Wyndham</td>
<td>2.25</td>
<td>2.75</td>
<td>2</td>
<td>1.75</td>
<td>2.1875</td>
</tr>
</tbody>
</table>

Figure 6.5: Hotels ranked by their overall ratings

The preceding query does all of the following:

- Gets all reviews grouped by hotels
- Adds up the individual review parameters for each hotel
- Gets the average individual review parameters by dividing the sum by the total number of reviews
- Calculates the overall rating as the average of all the review parameters

**Adding comments to Neo4j**

As discussed earlier, comments can be used by users to ask more questions or clarify something to other users. Since chronology is important, we will create a chain for the comments. The assumption here is that for a new question or clarification, a new comment chain will be started with the first comment in the chain being in response to the review being commented on.

Before we add comments, we should set up a constraint on comments to ensure that we don't create comments with the same ID, as shown in the following query:

```
neosh-sh ( )\$ CREATE CONSTRAINT ON (comment:Comment)
   ASSERT comment._id IS UNIQUE;
```
The output of the preceding query is as follows:

```
+-------------------+
| No data returned. |
+-------------------+

Constraints added: 1
```

To add a comment to the review, we can use the following query:

```
CREATE (comment:Comment{ _id:"df23c188-2349-11e5-8966-6c40089a9424", text:"What was wrong with the service?", created_on: 1391550607.342643})
WITH comment
MATCH (review:Review{ _id:"d120a06e-2331-11e5-bf11-6c40089a9424"}), (user:User{ email: "mahesh.lal@gmail.com"})
WITH review, user, comment
MERGE (review)<-[ :IN_REPLY_TO ]-(comment)<-[ :WROTE ]-(user)
RETURN review, comment, user
```

The output of the preceding query is as follows:

![Graph diagram showing the relationship between a review, comment, and user]

Figure 6.6: Adding comments to a review
To add a reply to an already existing comment, we can use the following query:

```sql
CREATE (new_comment:Comment{ _id:"a3da3c5c-2350-11e5-9006-6c40089a9424", text:"Some issues with the air conditioner which led to a sleepless night", created_on: 1391723407.342643})
WITH new_comment
MATCH (comment:Comment{ _id:"df23c188-2349-11e5-8966-6c40089a9424"}), (user:User{ email:"hale.orison@gmail.com"})
MERGE (user)-[:WROTE]->(new_comment)-[:IN_REPLY_TO]->(comment)
RETURN user, new_comment, comment
```

The output of the preceding query is as follows:

![Figure 6.7: Adding a reply to a comment](image)

We can add more comments to the review in the same way as we added the first one:

```sql
CREATE (comment:Comment{ _id:"1e0a80de-2353-11e5-86b5-6c40089a942", text:"Thanks for updating this.", created_on: 1390686607.342643})
WITH comment
MATCH (review:Review{ _id:"d120a06e-2331-11e5-bf11-6c40089a9424"}), (user:User{ email:"elijah.b@gmail.com"})
WITH review, user, comment
```

```sql
[ 68 ]
```
The output of the preceding query is as follows:

```
MATCH p = (review:Review{_id:"d120a06e-2331-11e5-bf11-6c40089a942"})<-[:IN_REPLY_TO*1..]-(comment:Comment)<-[:WROTE]-(user:User)
RETURN p
```

![Graph](image)

Figure 6.8: Adding additional comment to the review

To fetch the review along with its comments, we can use the following query:

```
MATCH p = (review:Review{ _id:"d120a06e-2331-11e5-bf11-6c40089a942" })<-[:IN_REPLY_TO*1..]-(comment:Comment)<-[:WROTE]-(user:User)
RETURN p
```
Considerations for modeling temporal data as chains

There are advantages to modeling temporal data as chains. The following points should be considered before modeling any data as a chain:

- Data should be modeled as a chain when the temporal relationship between them is important from a semantic perspective. Any communication with a request-response structure (for example, comments and e-mails) is suited to be modeled as a chain. Modeling the communication as a chain maintains the order in which the communication enters the system.
• In certain cases, there might be an implicit order in the data. For example, a visa application might go through multiple stages, which are in a particular order. Modeling these stages as chains would make sense.

• In certain cases, there might be a preferred order in which to present data. For example, most recent reviews make more sense, and hence the default for fetching reviews might be in reverse chronological order of the date of the stay. To optimize for the default scenario, we can model the data as a chain so that data can be fetched faster.

If the data doesn't fit into any of the categories mentioned in the previous bullets, then the data might not be suited to be modeled as a chain.

However, modeling data in chains has some downsides:

• Modeling the data as a chain will make it efficient for retrieval in a particular order, but might have performance penalties if the retrieval pattern needs to change

• Writing data to a chain that is ordered in reverse chronological order requires a complex query

**Summary**

In this chapter, we discussed modeling reviews and comments. We modeled comments as chains in order to maintain the semantic relationship between comments and replies. We discussed various queries that can be used to retrieve reviews and aggregation based on ratings. We also discussed the factors to be considered when deciding on modeling data as a chain.

In the next chapter, we will look at how we can model access control and construct queries that take into consideration the access control settings.
Modeling Access Control

In the previous chapters, we designed the database for an application that allows travelers to search for routes, view flights and hotels, check reviews for hotels, comment on reviews, and book flights. When multiple hotel chains operate using the same application (such as the one we are building), it helps if the hotel chains have access to modify the content that they wish to expose to the outside world.

In this chapter, we will explore:

• Creating access control structures in a graph
• Using access control structures to query and get selected data

Controlling access for content change

A hotel chain can have multiple hotels in different locations across cities or even countries, and each of these needs to edit its content. Employees of a hotel chain can be associated with particular hotels or regions. Assuming each hotel has autonomy in deciding and modifying their own content, we have the following scenarios to be addressed:

• Employees of a hotel chain should have access to modify the content for the hotels they have access to, depending on the access groups they are in
• Employees of a hotel shouldn't have access to modify any other hotel's content irrespective of the fact that there might be other hotels belonging to the same parent hotel chain
• Employees of a hotel chain shouldn't be able to access content of other hotel chains
Modeling hierarchies
To model employees and access control groups, we need to first modify our existing data to account for hierarchies in regions, countries, and cities. We also need to add hotel chains and their hierarchies. We can then apply the same practices used in modeling hierarchies to model access groups.

Modeling geographical regions
We already have airports and cities, which are geographical entities. We can add a couple of other entities such as country and region.

```
:Countries
    name:"United States Of America"
}
:Region
    name: "Europe Union"
}
```

Figure 7.1: Country and region

A country or a region is uniquely identified by its name.

We can represent the relationship between airports, cities, countries, and regions in the following way:
The previous diagram representing *Regions, countries, cities, and airports* can be generalized to represent a hierarchy in Neo4j.
Adding countries and regions to Neo4j

We can add a constraint to ensure the uniqueness of a name across countries, shown as follows:

```bash
neo4j-sh ?$ CREATE CONSTRAINT ON (country:Country)
    ASSERT country.name IS UNIQUE;
```

The output of the preceding query is as follows:

```
+-------------------+
| No data returned. |
+-------------------+
Constraints added: 1
```

To extract countries from cities, and connect cities to their respective countries, we can use the following query:

```cypher
MATCH (city:City)
WITH city
MERGE (country:Country{name: city.country})
WITH country, city
MERGE (country)-[:SUB_REGION]->(city)
RETURN city, country
```

The output of the preceding query is as follows:

![Figure 7.3: Extracting countries and connecting them to cities](image)
We should also add a constraint on region names being unique as shown:

```
neo4j-sh (?)$ CREATE CONSTRAINT ON (region:Region)
  ASSERT region.name IS UNIQUE;
```

The output of the preceding query is as follows:

```
+-------------------+
| No data returned. |
+-------------------+
Constraints added: 1
```

Now, we can add regions to our data model and connect them to the countries by creating a region hierarchy. The following query creates a region with the name **North America** and adds **Canada** and **United States of America** to the region as :SUB_REGION:

```
MATCH (city:City)
WITH city
MERGE (country:Country{name: city.country})
WITH country, city
MERGE (country)-[:SUB_REGION]->(city)
RETURN city, country
```

The output of the preceding query is as shown:

Figure 7.4: Creating North America as a region
We can add other regions to our data model using similar queries.

Add more regions using the regions.cqy file, which can be found with the code for this chapter.

The code can be downloaded from the publisher’s website or from https://github.com/maheshlal2910/neo4j_graph_data_modelling.

The following query returns the whole region hierarchy along with the airports:

```
MATCH path = (region:Region)-[:SUB_REGION*1..]->
  (city:City)-[:HAS_AIRPORT]->(airport:Airport)
RETURN path
```

The output of the preceding query is as follows:

![Figure 7.5: Region hierarchy with airports](image)
In a more general sense, cities and countries can also be considered to be regions. We can add a label :Region to city and country nodes. The following query can be used for it:

```sql
neo4j-sh (?)$ MATCH (city:City), (country:Country)
    SET city :Region, country :Region;
```

The output of the preceding query is as shown:

```
+-------------------+
| No data returned. |
+-------------------+
Labels added: 26
```

We can now proceed to the problem of modeling hotel chains, employees, and access control groups.

**Modeling hotel chains**

Hotel chains can be modeled as entities while hotels belong to chains.

![Hotel Chain Diagram](image)

Figure 7.6: Hotel chain
Modeling Access Control

Hotel chains can be uniquely identified by their name. The relationship between hotels and chains can be depicted as shown in the following figure:

Figure 7.7: Hotel chains and hotels

[Diagram of hotel chains and hotels]
Adding hotel chains to Neo4j

The following query adds a uniqueness constraint on the name of the hotel chain:

```bash
neo4j-sh (?)$ CREATE CONSTRAINT ON (chain:HotelChain)
    ASSERT chain.name IS UNIQUE;
```

The output of the preceding query is as follows:

```
+-------------------+
| No data returned. |
+-------------------+
Constraints added: 1
```

We can create a hotel chain and add hotels to that chain using the following query:

```cypher
CREATE (chain:HotelChain{name:"Hilton Hotels"})
WITH chain
MATCH (hotel:Hotel) WHERE hotel.name IN ['Hilton", "Double Tree"]
MERGE (hotel)-[:BELONGS_TO]->(chain)
RETURN hotel, chain;
```

The output of the preceding query is as follows:

![Figure 7.8: Creating hotel chains](image_url)
Add more regions using hotel_chains.cqy, which can be found with the code for this chapter.

The code can be downloaded from the publisher's website or from https://github.com/maheshlal2910/neo4j_graph_data_modelling.

The following query can be used to get the hierarchies of hotel chains, hotels, and regions:

```
MATCH p = (region:Region)-[:SUB_REGION*1..]->
  (city:City)-[:HAS_AIRPORT]->(airport:Airport)-
  [:HAS_HOTEL]->(hotel:Hotel)
WITH p, hotel
OPTIONAL MATCH (hotel:Hotel)-[:BELONGS_TO]->(hotelChain:HotelChain)
RETURN
EXTRACT( node in FILTER(n in NODES(p)
  WHERE "Region" IN LABELS(n))| node.name) as region,
EXTRACT( node in FILTER(n in NODES(p) WHERE
  "Country" IN LABELS(n))| node.name) as country,
EXTRACT( node in FILTER(n in NODES(p) WHERE
  "City" IN LABELS(n))| node.name) as city,
EXTRACT( node in FILTER(n in NODES(p) WHERE
  "Airport" IN LABELS(n))| node.code) as airport,
EXTRACT( node in FILTER(n in NODES(p) WHERE
  "Hotel" IN LABELS(n))| node.name) as hotel,
hotelChain.name as chain;
```

The output of the preceding query is as follows:

```
<table>
<thead>
<tr>
<th>region</th>
<th>country</th>
<th>city</th>
<th>airport</th>
<th>hotel</th>
<th>chain</th>
<th>parentChain</th>
</tr>
</thead>
<tbody>
<tr>
<td>North America</td>
<td>Canada</td>
<td>Toronto</td>
<td>YYZ</td>
<td>Four Points</td>
<td>Sheraton Group</td>
<td>null</td>
</tr>
<tr>
<td>North America</td>
<td>Canada</td>
<td>Toronto</td>
<td>YYZ</td>
<td>ALT Sheraton</td>
<td>Sheraton Group</td>
<td>null</td>
</tr>
<tr>
<td>North America</td>
<td>United States of America</td>
<td>New York</td>
<td>JFK</td>
<td>Hampton Inn</td>
<td>Airport Inn Hospitality</td>
<td>null</td>
</tr>
<tr>
<td>North America</td>
<td>United States of America</td>
<td>New York</td>
<td>LGA</td>
<td>LaGuardia Plaza</td>
<td>Plaza Group</td>
<td>null</td>
</tr>
<tr>
<td>North America</td>
<td>United States of America</td>
<td>New York</td>
<td>JFK</td>
<td>Fairfield Inn</td>
<td>Airport Inn Hospitality</td>
<td>null</td>
</tr>
<tr>
<td>North America</td>
<td>United States of America</td>
<td>Los Angeles</td>
<td>LAX</td>
<td>LAX</td>
<td>Sheraton</td>
<td>null</td>
</tr>
<tr>
<td>North America</td>
<td>United States of America</td>
<td>Las Vegas</td>
<td>LAS</td>
<td>Travelodge</td>
<td>Travelodge</td>
<td>null</td>
</tr>
<tr>
<td>North America</td>
<td>United States of America</td>
<td>Chicago</td>
<td>ORD</td>
<td>Embassy Suites</td>
<td>Ambassador Suites</td>
<td>null</td>
</tr>
<tr>
<td>North America</td>
<td>United States of America</td>
<td>Chicago</td>
<td>O'Hare</td>
<td>Hilton Hotels</td>
<td>null</td>
<td></td>
</tr>
<tr>
<td>North America</td>
<td>United States of America</td>
<td>Chicago</td>
<td>O'Hare</td>
<td>Hilton Hotels</td>
<td>null</td>
<td></td>
</tr>
<tr>
<td>North America</td>
<td>United States of America</td>
<td>Las Vegas</td>
<td>LAS</td>
<td>Hyatt</td>
<td>Hyatt Group</td>
<td>null</td>
</tr>
<tr>
<td>Asia</td>
<td>India</td>
<td>Mumbai</td>
<td>BOM</td>
<td>[J W Marriott Surat]</td>
<td>Marriott Group</td>
<td>null</td>
</tr>
<tr>
<td>Asia</td>
<td>India</td>
<td>Mumbai</td>
<td>BOM</td>
<td>[Ibis]</td>
<td>Ibis Hotels</td>
<td>Accor Hotels</td>
</tr>
<tr>
<td>Asia</td>
<td>Singapore</td>
<td>Singapore</td>
<td>SIN</td>
<td>Ambassador</td>
<td>Ambassador Suites</td>
<td>null</td>
</tr>
<tr>
<td>Asia</td>
<td>Istanbul</td>
<td>Istanbul</td>
<td>IST</td>
<td>Radisson</td>
<td>Radisson Group</td>
<td>null</td>
</tr>
<tr>
<td>Asia</td>
<td>Istanbul</td>
<td>Istanbul</td>
<td>IST</td>
<td>[KLM]</td>
<td>[KLM]</td>
<td>Airline Group</td>
</tr>
<tr>
<td>European Union</td>
<td>United Kingdom</td>
<td>London</td>
<td>LHR</td>
<td>[Vueling]</td>
<td>United Airlines</td>
<td>null</td>
</tr>
<tr>
<td>European Union</td>
<td>United Kingdom</td>
<td>London</td>
<td>LHR</td>
<td>[Vueling]</td>
<td>United Airlines</td>
<td>null</td>
</tr>
</tbody>
</table>
```

Figure 7.9: Regions, countries, cities, airports, hotels, and chains
In a few cases such as Sofitel, Mercure, Novotel, and Ibis, there is a parent chain of each hotel chain.

Since region hierarchies and hotel chains have been added to the model, we can now add employees and permissions.

**Modeling access control groups and employees**

Access control requires that we define access groups and employees.

Access groups and employees can be identified uniquely by their `_id` properties. Both of these also have a property name.

Access groups are linked to a hotel chain and will define what region or location the access group has permission to access for writes. Access groups’ levels and names will be different for different hotel chains.
Employees belong to a hotel chain and are associated with access groups. This association defines what they all have access to. The following diagram illustrates the relationship between hotels, hotel chains, access groups, and employees:
Access groups can be named differently and have a different granularity for different chains. For example, Ibis hotels have an access group named Europe, which is applicable for all the countries in Europe, and thus, members of this group can access all hotels in Europe. Sofitel hotels, on the other hand, have a finer grained access group called United Kingdom, which allows access to hotels in the United Kingdom. The parent chain Accor Hotels has an access group named European Union, which has access to Europe and United Kingdom.

For all further examples, we will add access groups to Accor hotels.

**Adding access groups to Neo4j**

We can create a uniqueness constraint on the access group _id using the following query:

```
neo4j-sh ( )$ CREATE CONSTRAINT ON 
    (accessGroup:AccessGroup) ASSERT accessGroup._id IS UNIQUE;
```

The output of the preceding query is as follows:

```
+-------------------+
| No data returned. |
+-------------------+
Constraints added: 1
```

To add an access group to a hotel chain for a particular region, we can use the following query:

```
MATCH (region:Region{name:"European Union"})-[:SUB_REGION*0..1]->(city)-[:HAS_AIRPORT]-(airport:Airport)-[:HAS_HOTEL]-(hotel:Hotel)-[:BELONGS_TO]->(chain:HotelChain{name:"Ibis Hotels"})
WITH hotel, chain
MERGE (accessGroup:AccessGroup{ _id:"089cd024-249c-11e5-b902-6c40089a9424"}) ON CREATE SET
accessGroup.name = "European Union"
WITH chain, hotel, accessGroup
CREATE UNIQUE (chain)-[:HAS_ACCESS_GROUP]-(accessGroup)-[:CAN_ACCESS]->(hotel)
RETURN chain, accessGroup, hotel
```
The output of the preceding query is as follows:

<table>
<thead>
<tr>
<th>MATCH (region:Region(name:&quot;European Union&quot;))[::SUB_REGION*0..1]-(::city)-[::HAS_AIRPORT]</th>
</tr>
</thead>
<tbody>
<tr>
<td>*(1) AccessGroup(2) Hotel(2) HotelChain(1)</td>
</tr>
<tr>
<td>(2) BELONGS_TO(2) CAN_ACCESS(2) HAS_ACCESS_GROUP(1)</td>
</tr>
</tbody>
</table>

Figure 7.12: Adding access group to a region for a hotel chain

Add more regions using `accor_subsidary_hotels_access_groups.cqy` that can be found with the code for this chapter. The code can be downloaded from the publisher's website or from [https://github.com/maheshlal2910/neo4j_graph_data_modelling](https://github.com/maheshlal2910/neo4j_graph_data_modelling).
To add an access group that can access other access groups, we can use the following query:

```
MATCH (subsidiaryAccessGroup:AccessGroup),
    (chain:HotelChain{name:"Accor Hotels"})
WHERE subsidiaryAccessGroup._id IN ['7506082e-24a2-11e5-b62b-6c40089a9424', '539487e2-24a2-11e5-bb1b-6c40089a9424', 'cef89d02-24a1-11e5-821c-6c40089a9424', '089cd024-249c-11e5-b902-6c40089a9424']
WITH subsidiaryAccessGroup, chain
MERGE (accessGroup:AccessGroup{ _id:"57096383-24a3-11e5-87db-6c40089a9424"}) ON CREATE SET
    accessGroup.name = "European Union"
WITH subsidiaryAccessGroup, accessGroup, chain
CREATE UNIQUE (chain)-[:HAS_ACCESS_GROUP]->
    (accessGroup)-[:CAN_ACCESS]->(subsidiaryAccessGroup)
WITH chain, accessGroup
MATCH path = (chain)-[:HAS_ACCESS_GROUP]-
    (accessGroup)-[:CAN_ACCESS*1..]->(:Hotel)-[:BELONGS_TO]->(:HotelChain)
RETURN path
```

The output of the preceding query is as follows:

![Figure 7.13: Adding access groups that can access other access groups](image-url)
Modeling Access Control

Add more regions using accor_access_groups.cqy, which can be found with the code for this chapter. The code can be downloaded from the publisher’s website or from https://github.com/maheshlal2910/neo4j_graph_data_modelling.

Adding employees to Neo4j

We can add a constraint on the employee _id using the following query:

```bash
neo4j-sh (?)$ CREATE CONSTRAINT ON (emp:Employee)
  ASSERT emp._id IS UNIQUE;
```

The output of the preceding query is as follows:

```
+-------------------+
| No data returned. |
+-------------------+
Constraints added: 1
```

The following query adds an employee to a hotel chain and assigns the employee to an access group:

```graphql
MATCH (chain:HotelChain{name:"Accor Hotels"}),
  (euAccess:AccessGroup{_id:"57096838-24a3-11e5-87db-6c40089a9424"})
WITH chain, euAccess
MERGE (employee:Employee{_id:17812}) ON CREATE
  SET employee.name = "Jeoffery Fraser"
WITH employee, chain, euAccess
CREATE UNIQUE (chain)-[:EMPLOYED_BY]-(employee)
  -[:MEMBER_OF]->(euAccess)
RETURN employee, euAccess, chain
```
The output of the preceding query is as follows:

Add more regions using employees.cqy that can be found with the code for this chapter. The code can be downloaded from the publisher's website or from https://github.com/maheshlal2910/neo4j_graph_data_modelling.
Querying the data model to find what is accessible to an employee

To find which hotels are accessible to an employee, we can traverse the :CAN_ACCESS relationships. The following query gets all the hotels accessible to an employee via all the groups the employee has access to, and also returns all the airports and locations of the hotels to which the employee has access:

```cypher
MATCH p = (chain:HotelChain)<-[[:EMPLOYED_BY]]-(employee:Employee{_id:17812})-[[:MEMBER_OF]]-(:AccessGroup)-[[:CAN_ACCESS*0..]]-(hotel:Hotel)-[:BELONGS_TO]->(hotelChain:HotelChain)
WITH p, hotel
MATCH (hotel)<-[[:HAS_HOTEL]]-(airport:Airport)<-[[:HAS_AIRPORT]]-(city:City)
RETURN p, hotel, airport, city
```

The output of the preceding query is as follows:

![Figure 7.15: Hotels accessible to members of the European Union access group of Accor hotels](image)
For an employee of a subsidiary of Accor hotels, the accessible hotels will be a smaller subset. The following query tries finding all hotels accessible to a different employee in a different hotel chain:

```cypher
MATCH p = (chain:HotelChain)<-[[:EMPLOYED_BY]]-(employee:Employee{id:78641})-[[:MEMBER_OF]]-(accessGroup:AccessGroup)-[:CAN_ACCESS*0..]->(hotel:Hotel)-[:BELONGS_TO]->(hotelChain:HotelChain)
WITH p, hotel
MATCH (hotel)<-[[:HAS_HOTEL]]-(airport:Airport)<-[[:HAS_AIRPORT]]-(city:City)
RETURN p, hotel, airport, city
```

The output of the preceding query is as follows:

![Diagram showing accessible hotels](image)

Figure 7.16: Hotels accessible to an employee of Sofitel who is member of the Greek access group
Summary
In this chapter, we explored how we can model access control in graphs. While we have created access groups according to the region, there might be different parameters on which we can create access groups. We also explored how to use the groups and accessible hotels to find which hotels are accessible to a particular employee.

In the next chapter, you will learn how to recommend hotels to travelers and analyzing data using Cypher.
In the previous chapters, you learned how to use model flights and cities as a graph and have written queries to return flight routes. We also added airports, hotels, reviews for hotels, and access groups that we could use to decide which access rights an employee has.

In this chapter, we will explore how we can run recommendations using the data we have, and also see if we can uncover some patterns using historical data.

**Recommending cities to travelers**

We know which cities the travelers have traveled to on the basis of the journeys they have been a part of. This allows us to make recommendations to a traveler as to where they could travel next. Using information about where a user has traveled, and some information about the city, we can recommend better. There are multiple pieces of information of the place can be added, one of them being the category or the type of city.

We can consider cities as belonging to one or more of the following categories:

- **Streets**: This includes cities where there is rich street art, street food, and so on
- **Cosmopolitan hotspots**: This includes cities that are cosmopolitan
- **Romantic**: This includes cities which couples consider for a romantic holiday
- **Historical importance**: This includes cities with historical importance
- **Architecture**: This includes cities with beautiful architecture, both modern and classical
- **Business**: This includes cities that are business centers
Recommendations and Analysis of Historical Data

These categories don't exist in our data and we will need to model them and associate them with cities.

**Modeling categories**

Categories can be modeled as nodes or labels. Modeling categories as labels is a simple approach. However, modeling categories as nodes is more flexible. A category modeled as a node allows us to represent hierarchies among categories, facilitates aggregation with ease, and also allows us to find the most relevant category using counts. While labels allow us to do aggregation, the resultant query will be difficult to understand. Modeling categories as nodes also allows us to add metadata to the category. The following figure suggests the model of a category node:

![Figure 8.1: Category node](image)

Categories have names and descriptions. They can be uniquely identified by their name. The following figure represents how a category will be related to a city:

![Figure 8.2: Cities and categories](image)
A city can have multiple categories and will be connected to all categories that it has by a :KNOWNS_FOR relationship.

**Creating categories in Neo4j**

We can create a constraint on the category name using the following query:

```
neo4j-sh (>)$ CREATE CONSTRAINT ON (c:Category)
           ASSERT c.name IS UNIQUE;
```

The output of the preceding query is as follows:

```
+-------------------+
| No data returned. |
+-------------------+
Constraints added: 1
```

**Cities and categories**

We can create a category using the following query:

```
CREATE (c:Category{name:"Streets", description:
  "Cities where there is a rich street art, street food etc."}) RETURN c;
```

The output of the preceding query is as follows:

![Figure 8.3: Adding a category](image)

Figure 8.3: Adding a category
You can add more categories using the categories.cqy files, which can be found with the code for this chapter. The code can be downloaded from the publisher's website or from https://github.com/maheshlal2910/neo4j_graph_data_modelling.

Cities can have multiple categories associated with them, for example, Mumbai is known for business as well as historical importance. We can connect a city to a category using the following query:

```cypher
MATCH (n:City{name:"Mumbai"}),
(c:Category{name:"Cosmopolitan Hotspot"})
CREATE UNIQUE (n)-[:KNOWN_FOR]->(c);
```

The output of the preceding query is as follows:

```
+-------------------+
| No data returned. |
+-------------------+
Relationships created: 1
```

You can connect more cities to categories using the add_categories_to_cities.cqy file that can be found with the code for this chapter. The code can be downloaded from the publisher's website or from https://github.com/maheshlal2910/neo4j_graph_data_modelling.

### Recommending cities based on previous travels

A traveler might pass through multiple cities while travelling, however, we can't count each city as a "traveled" city. The traveler might just be transiting through some of the cities. The following query gives us information about all the cities the traveler has travelled to:

```cypher
MATCH (passenger:Passenger)
  [:HAS_PASSENGER]-(b:Booking)-[:HAS_JOURNEY]->(:Journey)-[:BY_FLIGHT]->(:Flight)-[r]->(airport:Airport)
WITH DISTINCT b AS original_booking,
  COLLECT(airport) AS airports, passenger
```

```bash
[96]
```
WITH original_booking, FILTER(airport IN airports WHERE 1=LENGTH(FILTER (a IN airports WHERE a=airport))) AS distinct_airports, passenger
MATCH (airport:Airport)<-[[:HAS_AIRPORT]]-(city:City) WHERE airport IN distinct_airports
RETURN DISTINCT city.name;

The output of the preceding query is as follows:

<table>
<thead>
<tr>
<th>city.name</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;Los Angeles&quot;</td>
</tr>
<tr>
<td>&quot;London&quot;</td>
</tr>
<tr>
<td>&quot;New York&quot;</td>
</tr>
<tr>
<td>&quot;Mumbai&quot;</td>
</tr>
</tbody>
</table>

Using this information, we can now find out the categories that the traveler might be most interested in, and on the basis of the most common categories, we can recommend other cities satisfying those categories to travel to next. There might be categories that are of higher interest to a traveler, and we can use this information to find cities that the traveler might find more interesting. The following query calculates a travelers' category preferences and recommends cities that cover most of the categories:

```
MATCH (passenger:Passenger{email: "vishal.p@gmail.com"})<-[[:HAS_PASSENGER]]-(b:Booking)-[:HAS_JOURNEY]->(:Journey)-[:BY_FLIGHT]->(:Flight)-[r]-(airport:Airport)
WITH DISTINCT b AS original_booking, COLLECT(airport) AS airports, passenger
WITH original_booking, FILTER(airport IN airports WHERE 1=LENGTH(FILTER(a IN airports WHERE a=airport))) AS distinct_airports, passenger
MATCH (airport:Airport)<-[[:HAS_AIRPORT]]-(city:City) WHERE airport IN distinct_airports
WITH DISTINCT city
MATCH (city)-[[:KNOWN_FOR]]->(category:Category)
WITH DISTINCT category, COUNT(category) as relevance, COLLECT(city) as cities ORDER BY relevance DESC
MATCH (other_city:City)-[:KNOWN_FOR]->(category)
WHERE NOT other_city IN cities
```
Recommendations and Analysis of Historical Data

RETURN DISTINCT other_city.name,
    COLLECT(category.name), COUNT(category.name)
as relevance ORDER BY relevance DESC

The output of the preceding query is as follows:

<table>
<thead>
<tr>
<th>other_city.name</th>
<th>COLLECT(category.name)</th>
<th>relevance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Madrid</td>
<td>[Business, Streets, Historical Importance]</td>
<td>2</td>
</tr>
<tr>
<td>Paris</td>
<td>[Business, Historical Importance]</td>
<td>2</td>
</tr>
<tr>
<td>Istanbul</td>
<td>[Streets, Historical Importance]</td>
<td>2</td>
</tr>
<tr>
<td>Melbourne</td>
<td>[Business, Streets]</td>
<td>2</td>
</tr>
<tr>
<td>Sydney</td>
<td>[Business, Streets]</td>
<td>2</td>
</tr>
<tr>
<td>Athens</td>
<td>[Business, Historical Importance]</td>
<td>2</td>
</tr>
<tr>
<td>Singapore</td>
<td>[Business, Cosmopolitan Hotspot]</td>
<td>2</td>
</tr>
<tr>
<td>Toronto</td>
<td>[Business]</td>
<td>1</td>
</tr>
<tr>
<td>Las Vegas</td>
<td>[Streets]</td>
<td>1</td>
</tr>
<tr>
<td>Chicago</td>
<td>[Business]</td>
<td>1</td>
</tr>
<tr>
<td>Rome</td>
<td>[Historical Importance]</td>
<td>1</td>
</tr>
</tbody>
</table>

Figure 8.4: Cities that might interest the traveler most

**Recommending cities on the basis of other travelers**

We can recommend cities to visit on the basis of other travelers as well. One of the simplest scenarios to consider is, if Alice and Bob have visited the same city, we can recommend other cities visited by Bob to Alice. The query is as follows:

```
neo4j-sh (?)$
//get all cities the traveller has been to
MATCH (passenger:Passenger{email:"vishal.p@gmail.com"})
    <-[:HAS_PASSENGER]-(:Booking)-[:HAS_JOURNEY]->
    (:Journey)-[:BY_FLIGHT]->(Flight)-[r]-(airport:Airport)
WITH DISTINCT b AS original_booking,
    COLLECT(airport) AS airports, passenger
WITH original_booking, FILTER(airport IN airports
    WHERE 1=LENGTH(FILTER(a IN airports WHERE
    a=airport)))) AS distinct_airports, passenger
MATCH (airport:Airport)<-[::HAS_AIRPORT]-(city:City)
WHERE airport IN distinct_airports
WITH city, passenger
//fetch other passengers who have travelled to this city
MATCH (city)-[::HAS_AIRPORT]->(a:Airport)-[rel]-
    (:Flight)<-[::BY_FLIGHT]-(:Journey)<-[::HAS_JOURNEY]-
    (booking:Booking)-[::HAS_PASSENGER]->
    (other_passenger:Passenger)
```
WHERE other_passenger <> passenger
WITH DISTINCT other_passenger, city
//find all bookings of other passengers who have
//travelled to same city
MATCH (other_passenger)<-[[:HAS_PASSENGER]]-
  (other_booking:Booking)
WITH DISTINCT other_booking, city
//find all cities that the other traveller has
//visited and filter out the cities that have been already visited
MATCH (other_booking)-[:HAS_JOURNEY]->(j:Journey)-[:BY_FLIGHT]-
  ->(:Flight)-[r]-(other_airport:Airport)
WITH DISTINCT other_booking._id as booking, COLLECT(DISTINCT
  j._id) as journey, COLLECT(other_airport)
as other_airports, city
WITH FILTER(unique_airport IN other_airports WHERE
  1=LENGTH(FILTER(x IN other_airports
  WHERE x=unique_airport))) AS destination_airports,
  COLLECT(city) as visited
UNWIND destination_airports as airport
MATCH (airport:Airport)<-[[:HAS_AIRPORT]]-(other_city:City)
WHERE NOT other_city IN visited
RETURN DISTINCT other_city.name as recommended_cities;

The output of the preceding query is as follows:

+--------------------+
| recommended_cities |
+--------------------+
| "Singapore"        |
| "Melbourne"        |
+--------------------+
2 rows

There can be other variants of this recommendation where we recommend cities that
Bob has visited and belong to categories that Alice is interested in. The possibilities
for recommendations are bound by the data and how we can derive connections
between them.
Recommendations and Analysis of Historical Data

**Recommending hotels to travelers**

Reviews and ratings help travelers to decide on a hotel to stay at when travelling to or transiting through a particular place. However, reviews are dependent on people's personal tastes. A few other inputs that can help travelers make a better decision are:

- Hotels which are from the same chain
- Hotels which other similar travelers have stayed at
- Hotels in a particular price range

These parameters aren't well defined, and we will define each of these better when we explore each scenario. Also, these aren't the only parameters that necessarily need to be considered, as recommendations can be made around any set of parameters.

It's easier to start with recommending hotels from the same chain that the traveler has visited earlier. We will assume that a traveler has visited a hotel if he has written a review for it. In all the queries for the recommendation of a hotel, we have constrained the search to an airport since they are mostly transit hotels.

**Recommending hotels from the same chains**

In the following query, we search hotels at the Melbourne airport that belong to the same chain of hotels that the traveler has stayed at earlier:

```sql
neo4j-sh (\$)\$ MATCH (user:User{email:"mahesh.lal@gmail.com"})-[WROTE]->(:Review)-[FOR_HOTEL]-(stayed:Hotel)-[BELONGS_TO*1..]->(chain:HotelChain)
WITH chain, stayed
MATCH (airport:Airport{code:"MEL"})-[HAS_HOTEL]->(hotel:Hotel)-[BELONGS_TO*1..]->(chain)
RETURN DISTINCT hotel.name as Hotel, COLLECT(DISTINCT chain.name) as Hotel_Groups,
COLLECT(DISTINCT stayed.name) AS Previous_Stays ;
```

The output of the preceding query is as follows:

<table>
<thead>
<tr>
<th>Hotel</th>
<th>Hotel_Groups</th>
<th>Previous_Stays</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;Ibis&quot;</td>
<td>['Ibis Hotels','Accor Hotels']</td>
<td>['Ibis','Sofitel']</td>
</tr>
</tbody>
</table>

1 row
Recommending hotels visited by similar travelers

The similarity of one traveler to another depends on multiple factors. We can say that the travelers who have stayed in the same hotels are similar. The following query recommends hotels in descending order of the number of similar travelers who have stayed at the hotel:

```
MATCH (user:User{email:"mahesh.lal@gmail.com"})-[[:WROTE]]->(:Review)-[:FOR_HOTEL]->(stayed:Hotel)<-[[:FOR_HOTEL]]-(:Review)<-[[:WROTE]]-(other_traveller:User)
WHERE NOT other_traveller = user
WITH other_traveller
MATCH (other_traveller)-[:WROTE]->(:Review)-[:FOR_HOTEL]->(hotel:Hotel)<-[[:HAS_HOTEL]]-(airport:Airport{code:"IST"})
RETURN
DISTINCT hotel.name as Hotel,
COLLECT(DISTINCT other_traveller.name) AS Similar_travellers,
COUNT (DISTINCT other_traveller) AS number_of_similar_travellers_who_stayed_here
ORDER BY number_of_similar_travellers_who_stayed_here DESC
```

The output of the preceding query is as follows:

<table>
<thead>
<tr>
<th>Hotel</th>
<th>Similar_travellers</th>
<th>number_of_similar_travellers_who_stayed_here</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radisson</td>
<td>[Abel AI, Shambhu Dayal, Sidique T, Dominique Shepard]</td>
<td>4</td>
</tr>
<tr>
<td>WOW</td>
<td>[Shambhu Dayal]</td>
<td>1</td>
</tr>
</tbody>
</table>

Figure 8.5: Recommended hotels based on similar people

We can also tweak the same query to recommend hotels based on an average rating given to them by similar travelers. Before we try the query, we should add `overall_rating` to each review, which is an average of ratings on all parameters within a review, as shown:

```
neo4j-sh (?)$ MATCH (review:Review)
SET review.overall_rating = toFloat(review.value_for_money + review.food +
review.comfort + review.service)/4;
```
Recommendations and Analysis of Historical Data

The output of the preceding query is as follows:

```
+-------------------+
| No data returned. |
+-------------------+

Properties set: 159
```

We can now write a query to recommend hotels based on average ratings by similar travelers:

```plaintext
MATCH (user:User{email:"mahesh.lal@gmail.com"})-
[:WROTE]-(:Review)-[:FOR_HOTEL]->(stayed:Hotel)
<-[:FOR_HOTEL]-(:Review)<-[:WROTE]-(other_traveller:User)
WHERE NOT other_traveller = user
WITH other_traveller
MATCH (other_traveller)-[:WROTE]->
(r:Review)-[:FOR_HOTEL]->(hotel:Hotel)
<-[:HAS_HOTEL]-(airport:Airport{code:"IST"})
RETURN
DISTINCT hotel.name as Hotel,
COLLECT(DISTINCT other_traveller.name) AS Similar_travellers,
SUM(r.overall_rating)/COUNT (DISTINCT
other_traveller) AS avg_rating_by_similar_travellers
ORDER BY avg_rating_by_similar_travelers DESC
```

The output of the preceding query is as follows:

<table>
<thead>
<tr>
<th>Hotel</th>
<th>Similar_travellers</th>
<th>avg_rating_by_similar_travellers</th>
</tr>
</thead>
<tbody>
<tr>
<td>WOW</td>
<td>[Shambhu Deyal]</td>
<td>6</td>
</tr>
<tr>
<td>Radisson</td>
<td>[Abel Ali, Shambhu Deyal, Sadique T, Dominique Shepard]</td>
<td>5.875</td>
</tr>
</tbody>
</table>

Figure 8.6: Recommending hotels based on average rating by similar travelers

**Recommending hotels that match a price range**

Considering that a traveler has stayed at multiple places, we can find the max price of the hotels visited. Based on this price, we can even suggest cheaper hotels at a particular location, as shown:

```plaintext
MATCH (user:User{email:"brian.heritage@hotmail.com"})-
[:WROTE]-(:Review)-[:FOR_HOTEL]->(hotel:Hotel)
WITH MAX(hotel.price) AS max_price
MATCH (airport:Airport{code:"ORD"})-[:HAS_HOTEL]->(hotel:Hotel)
```

---

[102]
WHERE hotel.price <= max_price  
RETURN hotel.name, hotel.price

The output of the preceding query is as follows:

<table>
<thead>
<tr>
<th>hotel.name</th>
<th>hotel.price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Embassy Suites</td>
<td>150</td>
</tr>
<tr>
<td>Double Tree</td>
<td>150</td>
</tr>
</tbody>
</table>

Figure 8.7: Recommending hotels based maximum price paid for a hotel historically

Improving recommendations
Though we have relied on the data already present to recommend hotels, there are several other parameters that can be used to recommend hotels. Recommendations can be improved by capturing more data for the user and increasing the data captured about hotels, for example, age of the user, the star rating of a hotel, assigned categories to hotels, and so on.

Analysis of the historical data
We have explored how to use the data model to enable a traveler to find what they need. With this data and some clever querying, we can also discover some trends that can help the businesses. Given we have the year, month, and day of bookings and hotel stays, we can venture into analyzing data and behavior patterns of individuals, and how it affects the businesses (hotels and airlines).

Querying to discover patterns
Bookings are not spread across the year evenly. There will always be months when the number of bookings made far exceeds the number of bookings during other months. The following query gives the number of bookings made for each month:

```
neo4j-sh (?)$ MATCH (booking:Booking)  
WITH COLLECT(booking) AS bookings, booking  
RETURN DISTINCT booking.month AS month, COUNT(bookings) AS num_of_bookings  
ORDER BY num_of_bookings DESC;
```
The output of the preceding query is as follows:

```
+-------------------------+
| month | num_of_bookings |
+-------------------------+
| 12    | 7               |
| 10    | 3               |
| 1     | 3               |
| 3     | 1               |
+-------------------------+
4 rows
```

Bookings are generally made in advance, and journey dates are different from the booking dates. As a corollary, peak journey months might be different as compared to peak booking months. Information about this can help in planning out promotional offer schedules to attract more sales. The following query gives us insight into when people travel the most:

```
neo4j-sh (?)$ MATCH (journey:Journey)
WITH COLLECT(journey) AS journeys, journey
RETURN DISTINCT journey.month AS month, COUNT(journeys) AS num_of_journeys
ORDER BY num_of_journeys DESC;
```

The output of the preceding query is as follows:

```
+-------------------------+
| month | num_of_journeys |
+-------------------------+
| 1     | 7               |
| 3     | 3               |
| 11    | 2               |
| 5     | 2               |
| 4     | 1               |
+-------------------------+
5 rows
```

Certain travelers travel in a particular season- or month-defined range of days. Having access to information about when a person is likely to travel can help in designing offers and personalized promotions. The following query fetches information about when a particular traveler travels:

```
neo4j-sh (?)$ MATCH (p1:Passenger{email:"mahesh.lal@gmail.com"})
<-[:HAS_PASSENGER]-(:Booking)-[:HAS_JOURNEY]->
(journey:Journey)
WITH COLLECT(journey) AS journeys, journey, p1
```
RETURN DISTINCT journey.month AS month, COUNT(journeys) AS count_journeys, p1.name as traveller_name ORDER BY count_journeys DESC;

The output of the preceding query is as follows:

<table>
<thead>
<tr>
<th>month</th>
<th>count_journeys</th>
<th>traveller_name</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4</td>
<td>&quot;Mahesh Lal&quot;</td>
</tr>
<tr>
<td>11</td>
<td>2</td>
<td>&quot;Mahesh Lal&quot;</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
<td>&quot;Mahesh Lal&quot;</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>&quot;Mahesh Lal&quot;</td>
</tr>
</tbody>
</table>

4 rows

Hotels get reviews throughout the year, and there are times when we might want to see how the average ratings of a hotel change in a year. The following query gives us an insight into how a hotel chain has been rated over the past three years:

MATCH (chain:HotelChain{name:"Hilton Hotels"})[:BELONGS_TO]-(hotel:Hotel)[:FOR_HOTEL]-(review:Review)
WITH review.stay_year as year, SUM(review.overall_rating) AS total_rating, COUNT(review) AS total_reviews, chain.name as group
RETURN DISTINCT year, SUM(total_rating/total_reviews) as avg_rating, total_rating, total_reviews, group
ORDER BY avg_rating DESC

The output of the preceding query is as follows:

<table>
<thead>
<tr>
<th>year</th>
<th>avg_rating</th>
<th>total_rating</th>
<th>total_reviews</th>
<th>group</th>
</tr>
</thead>
<tbody>
<tr>
<td>2015</td>
<td>2.75</td>
<td>0.25</td>
<td>3</td>
<td>Hilton Hotels</td>
</tr>
<tr>
<td>2014</td>
<td>4.625</td>
<td>47.5</td>
<td>18</td>
<td>Hilton Hotels</td>
</tr>
<tr>
<td>2013</td>
<td>2.372727272727273</td>
<td>25</td>
<td>11</td>
<td>Hilton Hotels</td>
</tr>
</tbody>
</table>

These are examples of a much larger set of analysis queries that can be run on the existing data.
Summary
In this chapter, you learned how to recommend hotels and cities to travel to using data that has been stored in Neo4j. We also explored a few queries that analyzed historical data and gave us some useful statistics. The next chapter guides you on where to go from here.
In the previous chapters, we saw examples of how to model various types of systems by taking examples of subsystems of a travel booking application. Taking a relatively straightforward graph problem, we expanded the problem statement and plotted more information on the graph. We explored the details of how to model certain systems and discussed design decisions. While we have covered a wide variety of designs decisions that can be adopted for different scenarios, the examples covered are by no means exhaustive. For example, we can enhance the user experience by adding location-based features for the travelers, and we can build more information into the Bookings subgraph by allowing for sequencing among the journeys of a booking.

**There is no correct model**

Modeling is a balancing act between the present and the future. It is important to understand that a data model is never perfect for all the problems that we might try to solve. We make compromises on certain parameters, while optimizing for others. Given more information and insight into the future of the business, the current model might feel inadequate. This is not an exception, and should be expected. Redesigning and data remodeling is a process that repeats itself multiple times over a product's life cycle.
Further reading and exploration

Graphs are being widely used in multiple domains, including, but not limited to, medical research, transportation, auditing, and financial risk analysis. For finding out more about modeling, the Neo4j mailing list on Google Groups is a good place. Occasionally, there are interesting modeling problems that people get down to solving. Alternately, a showcase of which problems people are solving using graphs in general and Neo4j in particular can be found at http://gist.neo4j.org/. For more use cases where Neo4j has been used, http://neo4j.com/use-cases/ is a good resource. Following @neo4j on Twitter is a good way to keep up with the happenings in the Neo4j world.

What to watch out for while using Neo4j

While Neo4j is a really handy tool and graphs are a good way to represent data, they are not suited for every single problem that is out there. There are definitely good cases where we can use an RDBMS more effectively. For example, if the application’s main task is to aggregate and crunch on data that fits into a single table, then RDBMS is a better option. For other cases such as profiles and user preferences, it makes more sense to store them in a DocStore. Also, large documents are not meant to be stored in Neo4j. For full-text querying apart from querying based on field/label, Neo4j might only be a part of the solution; something such as Solr or Elasticsearch should be used along with Neo4j to get the full-text search working at scale. Caching is best left to solutions such as memcached. While graphs are a great tool, overusing them and trying to fit a non-graph use case into a graph will more often than not result in failure or at least the cost of maintenance will be prohibitively high.

Another limitation of Neo4j (more of a limitation of graphs than Neo4j), as with all native graph stores, is that it can’t be sharded across machines. If we discover that the graph is going to increase beyond a certain size on the disk, or exceed the limits on numbers of nodes and relationships (32 billion nodes and 65 billion relationships), we should think of ways of restructuring the data in the graph so that it helps in sharding. A few practices that can help when we have to eventually partition the database are:

- Identifying relationships that can be turned to properties. If done well and indexed, the properties can act as implicit relationships. This reduces the interconnectedness of a graph, allowing us to partition it. Supernodes are candidates for conversion to properties. They are nodes to which hundreds, thousands or millions of other nodes are linked by relationships.

[ 108 ]
• If the problem domain is a large and complex interaction of multiple subdomains and is difficult to fit into one graph, modeling each of these domains in a separate graph might be beneficial. Relationships across subdomains can be represented by properties.

If we keep these caveats in mind while designing our graph data models, we can go a long way before hitting performance and other engineering issues.
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