

IN4MATX 133: User Interface Software

Lecture 16: Databases and Local Storage

Today's goals

By the end of today, you should be able to...

- Differentiate relational from non-relational databases
- Explain the advantages of each style of database
- Use IndexedDB to implement a non-relational database

Today is a crash course in databases
CS 122A and 122B provide
substantially more depth

Data storage

- What happens when we refresh the A4 sleep tracking app?
 - We lose all of the data we logged
- This is obviously not ideal
 - We have to tell the browser, app, etc. to store it

Data storage

- Data can be stored locally on a device
 - Android and iOS allow apps to store some data
 - Capacitor provides (good) libraries for using local storage

Local Storage

- In Ionic, can store key-value pairs
 - Keys must be strings, values can be any type
- This is actually a non-relational database!
 - More on this in a few slides

Local Storage

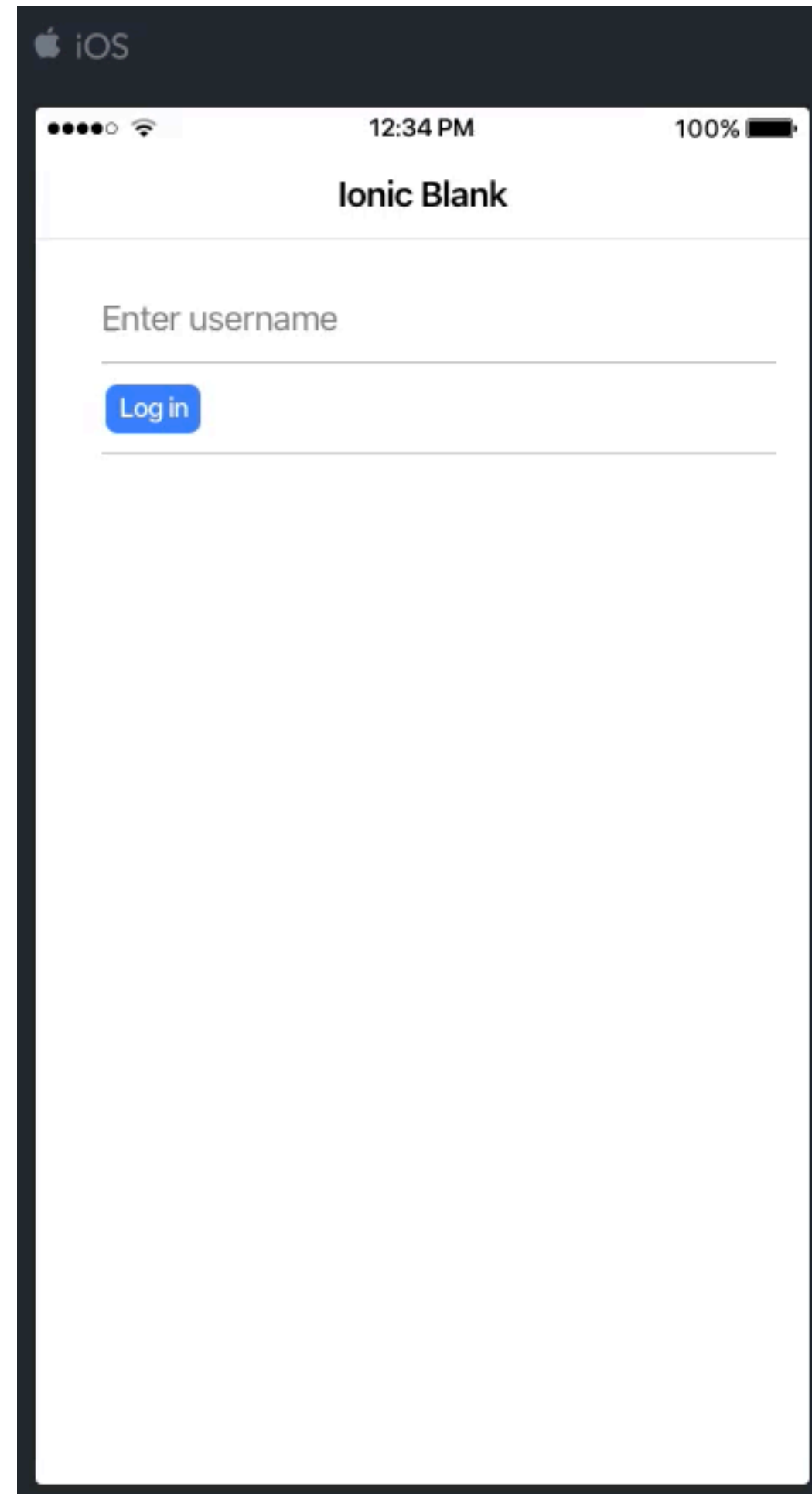
- Capacitor provides a cross-platform storage API

```
import { Storage } from '@capacitor/storage';
```

```
Storage.get({key: 'keyName'}).then((data) => {  
  console.log(data.value);  
});
```

```
Storage.set({key: 'keyName', value: 'value'}).then(() => {  
  console.log("set value");  
});
```

Local Storage



**If we can store data on devices,
why do we need databases?**

Databases

- Provide reliability
 - You can get your data back if your phone dies or you get a new phone
- Provide cross-device support
 - Allow you to see and modify the same data across a phone and a desktop, for example

Databases

- Are more than files stored in the cloud
 - Can be “queried” efficiently to get subsets of data
- Two main approaches to making databases
 - Relational databases: MySQL, Postgres
 - Non-relational databases: MongoDB, Firebase, IndexedDB
- Transaction: any add/delete/update/etc. made to a database

Databases

Relational databases

- Everything is organized into tables
- Tables contain columns with predefined names and data types
- Tables “relate” to one another by having overlapping or similar columns
 - Minimizes redundancy and keeps order
- Every data entry is a row of a table

<https://www.neonrain.com/blog/mysql-vs-mongodb-looking-at-relational-and-non-relational-databases/>

<https://www.mongodb.com/scale/relational-vs-non-relational-database>

Databases

Relational databases

Relational

Person:

Pers_ID	First_Name	Last_Name	City
1	Dexter	Lanasa	Vancouver
2	Ava	Crim	Denver
3	Michael	Plumer	New York City
4	Olivia	Conlin	Dallas
5	Sophia	Hassett	Atlanta
6	Mason	Mora	San Francisco

Phone Numbers:

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79	555-555-5555	Home	4
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Databases

Relational databases

```
CREATE TABLE IF NOT EXISTS tasks (  
  task_id INT AUTO_INCREMENT,  
  title VARCHAR(255) NOT NULL,  
  start_date DATE,  
  due_date DATE,  
  status TINYINT NOT NULL,  
  priority TINYINT NOT NULL,  
  description TEXT,  
  PRIMARY KEY (task_id)  
) ENGINE=INNODB;
```

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Databases

Non-relational databases

- Everything is organized into objects
- There are no restrictions on how objects are structured
- Every data entry is an object, or “document”
 - Documents may be structured differently from one another

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<https://www.mongodb.com/scale/relational-vs-non-relational-database>

Databases

Non-relational databases

MongoDB
Document

```
{
  first_name: 'Dexter',
  last_name: 'Lanas',
  city: 'Vancouver',
  location: [45.123,47.232],
  phones: [
    { phone_number: '111-111-1111',
      type: mobile,
      person_id: 1, ... },
    { phone_number: '444-444-4444',
      type: home,
      person_id: 1, ... },
    { phone_number: '777-777-7777',
      type: office,
      person_id: 1, ... },
  ]
}
```

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Databases

Non-relational databases

- There is no well-defined enforced structure
- That said, flatter structures are generally better

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<https://www.mongodb.com/scale/relational-vs-non-relational-database>

Databases

Non-relational databases

```
{  
  // This is a poorly nested data architecture, because iterating the children  
  // of the "chats" node to get a list of conversation titles requires  
  // potentially downloading hundreds of megabytes of messages  
  "chats": {  
    "one": {  
      "title": "Historical Tech Pioneers",  
      "messages": {  
        "m1": { "sender": "ghopper", "message": "Relay malfunction found. Cause: moth." },  
        "m2": { ... },  
        // a very long list of messages  
      },  
    },  
    "two": { ... }  
  }  
}
```

<https://firebase.google.com/docs/database/ios/structure-data>

Databases

Non-relational databases

```
{
  // Chats contains only meta info about each conversation stored under the chats's unique ID
  "chats": {
    "one": {
      "title": "Historical Tech Pioneers",
      "lastMessage": "ghopper: Relay malfunction found. Cause: moth."
    },
    "two": { ... }
  },
  // Messages are separate from data we may want to iterate quickly but still easily paginated and queried,
  // and organized by chat conversation ID
  "messages": {
    "one": {
      "m1": {
        "name": "eclarke",
        "message": "The relay seems to be malfunctioning."
      },
      "m2": { ... }
    },
    "two": { ... }
  }
}
```

<https://firebase.google.com/docs/database/ios/structure-data>

Question

Which database structure will be best for retrieving all first names?

- A** The relational database
- B** The non-relational database
- C** They will be about the same
- D** I'm not sure
- E** [space intentionally left blank]

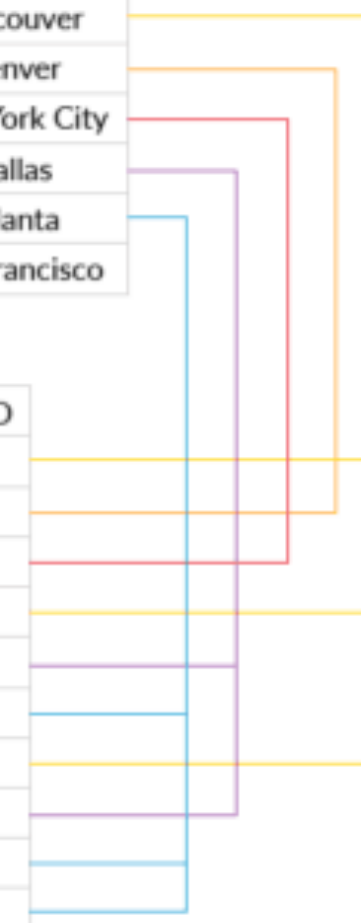
Relational

Person:

Pers_ID	First_Name	Last_Name	City
1	Dexter	Lanasa	Vancouver
2	Ava	Crim	Denver
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4	Olivia	Conlin	Dallas
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Non-relational

```
{  
  first_name: 'Dexter',  
  last_name: 'Lanas',  
  city: 'Vancouver',  
  location: [45.123,47.232],  
  phones: [  
    { phone_number: '111-111-1111',  
      type: mobile,  
      person_id: 1, ... },  
    { phone_number: '444-444-4444',  
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      person_id: 1, ... },  
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      type: office,  
      person_id: 1, ... },  
  ]  
}
```

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Relational

Person_ID	First_Name	Last_Name	City
1	Dexter	Lanas	Vancouver
2	Ava	Clin	Denver
3	Michael	Plumer	New York City
4	Olivia	Condo	Dallas
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A

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B

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C

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D

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E

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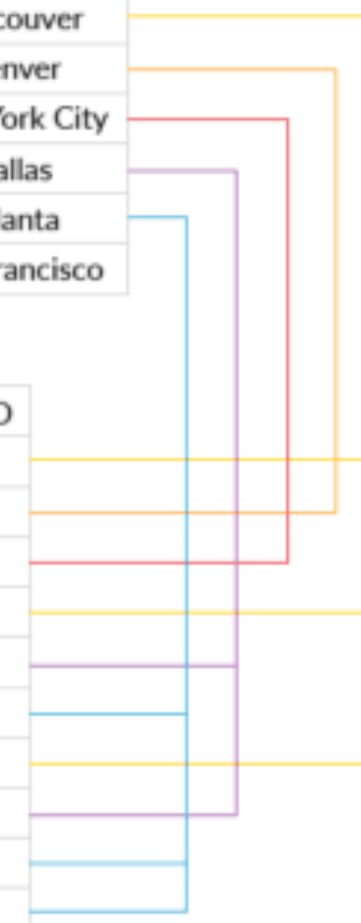
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Question

Which database structure will be best for retrieving all phone numbers?

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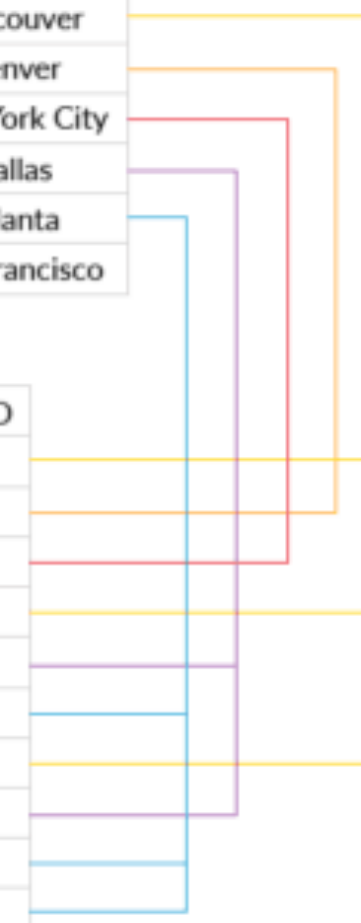
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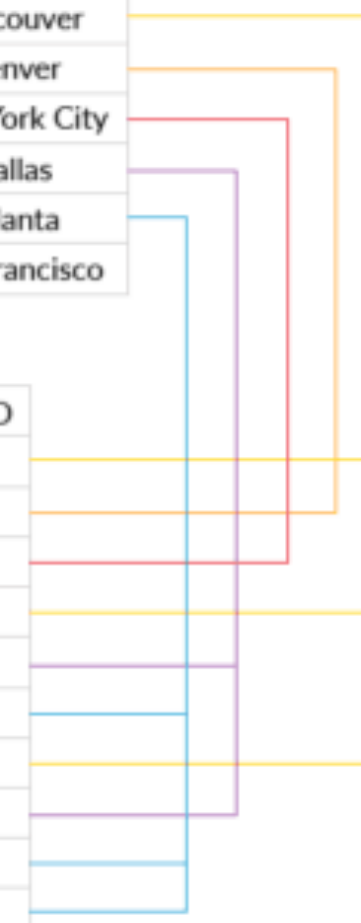
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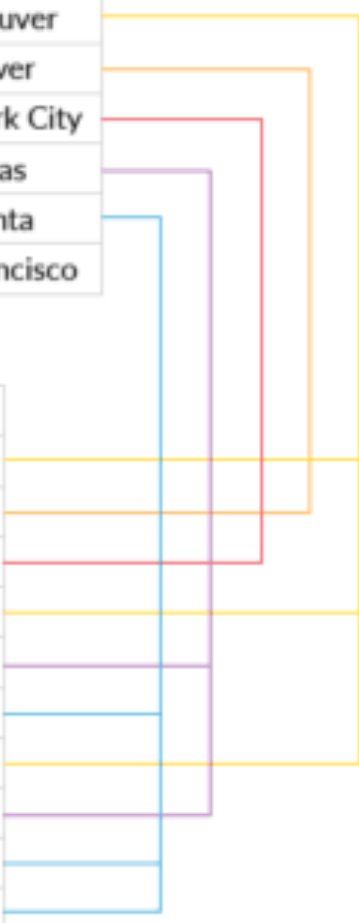
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}
```

Databases

Advantages of relational databases

- Relational databases support better querying
 - Provide *languages* for querying, such as Structured Query Language (SQL)
 - Those languages can be used to ask for specific tables or even join data across tables
 - “Give me the first name of every user whose phone number starts with 949”

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Databases

Advantages of relational databases

- Relational databases are more organized
 - Because field types are defined, data reliably follows that structure
- Relational databases are more reliable
 - Structure is enforced when new data is added
 - Transactions are atomic, so it's easy to “get” the current state of the database

<https://www.neonrain.com/blog/mysql-vs-mongodb-looking-at-relational-and-non-relational-databases/>
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Databases

Advantages of non-relational databases

- Non-relational databases support more flexibility
 - Structure imposes restrictions
 - Adding a new field (column) can mess up a relational database
- Non-relational databases are faster for simple operations
 - It's much easier to “watch all the files” than to query and index many rows across multiple tables

<https://www.neonrain.com/blog/mysql-vs-mongodb-looking-at-relational-and-non-relational-databases/>
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Databases

Relational vs. Non-relational

- Relational databases tend to be used in Enterprise, large-scale applications
 - It's important that data conforms to standards
 - It's important to robustly query large amounts of data
- Non-relational databases tend to be used in smaller applications
 - Data flexibility is valuable
 - Data is small enough to reliably retrieve and parse
- That said, plenty of large apps use non-relational databases and vice versa

Databases vs. Local Storage

- Who needs access to the data?
 - Just the user, or others?
 - As a developer, do you need access?
- Is the data sensitive?
- Is the data valuable enough that it should not be lost?

Databases vs. Local Storage

- Databases are crucial if more than the local device needs access
 - Cross-device app: [facebook.com](https://www.facebook.com) and the mobile app need your profile information
 - Developer: to understand habits across users or provide a data-driven service
- Some privacy can be preserved if data is only stored locally
- Which to use depends on the type of data and context

One non-relational database: IndexedDB

IndexedDB

- Proposed in 2015, standardized in 2021
- Native database support in browsers
- Pretty good compatibility these days
- Apple had proposed a relational version (SQLite), but other browsers declined to implement it



Chrome	Edge [*]	Safari	Firefox	Opera	IE	Chrome for Android	Safari on iOS [*]	Samsung Internet
		3.1-7					3.2-7.1	
4-10		² 7.1-9.1	2-3.6				² 8-9.3	
11-22 ⁻		10-14	4-9 ⁻				10-14.4	
23 ⁻	¹ 12-18	³ 14.1	10-15 ⁻	10-12.1	6-9		³ 14.8	
24-132	79-131	15-18.2	16-134	15-113	¹ 10		15-18.2	4-26
133	132	18.3	135	114	¹ 11	132	18.3	27
134-136		18.4-TP	136-138				18.4	

IndexedDB

- Client-side database
 - No communication across devices, not “cloud” storage
 - If your phone dies, the data is gone
- Some concerns about space, and operating system reclaiming space

IndexedDB

The best storage engine natively supported in browsers. Pros: free, available everywhere, widely used. Cons: OS may delete data to reclaim space, data not easily exportable, encryption not available

Pros

- Free
- Available in browser
- Query Support

Cons

- Data loss due to OS reclaiming space
- No support for encryption
- Limited storage capacity
- Difficult data export

IndexedDB

- So, what database advantages is it really providing?
 - Some structure and organization, primarily
 - A simpler API for demo purposes
 - Look at other classes for more examples or depth :-)

IndexedDB

The best storage engine natively supported in browsers. Pros: free, available everywhere, widely used. Cons: OS may delete data to reclaim space, data not easily exportable, encryption not available

Pros

- Free
- Available in browser
- Query Support

Cons

- Data loss due to OS reclaiming space
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IndexedDB

Getting some data



My grocery list

Grocery item Quantity

IndexedDB

Add item

```
this.dbService.add('objectStore', {item}).subscribe((value) => {  
    console.log(value);  
});  
}
```


IndexedDB

Get values

```
this.dbService.getAll('objectStore').subscribe((objects) => {  
  objects.forEach((object:any) => {  
    console.log(object);  
  })  
});
```

IndexedDB

Other methods

- Other library functions can implement other database methods
 - Update
 - Delete
 - Clear database

IndexedDB

Database Configuration

Store schema, id field that auto-increments

```
const dbConfig: DBConfig = {
  name: 'db',
  version: 1,
  objectStoresMeta: [{
    store: 'objStore',
    storeConfig: { keyPath: 'id', autoIncrement: true },
    storeSchema: [
      { name: 'name', keypath: 'name', options: { unique: false } },
      ...
    ]
  }]
};
```

IndexedDB

Is it really non-relational?

- It is technically an “Object database”, which stores data as objects
 - Think Object-oriented programming
- Relational databases store data as tables
 - Think rows/columns, like Google Sheets or Excel
- Because objects are flexible in structure, object databases are typically considered non-relational
 - But, the config still names fields

https://en.wikipedia.org/wiki/Object_database

Today's goals

By the end of today, you should be able to...

- Differentiate relational from non-relational databases
- Explain the advantages of each style of database
- Use IndexedDB to implement a non-relational database

IN4MATX 133: User Interface Software

Lecture 16: Databases and Local Storage