How to control an Arduino via the web

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Introduction

In this presentation, I will describe:

- How to control an Arduino's pin via the web using the Django web framework.

Overview

Throughout this tutorial, I will show you how to create an Django application.

It will consist of a:

1. A public website that will allow you to control an Arduino's pins.

Getting started

Create a new directory named "django_tutorial" in `C:/Users/%USER%/`.

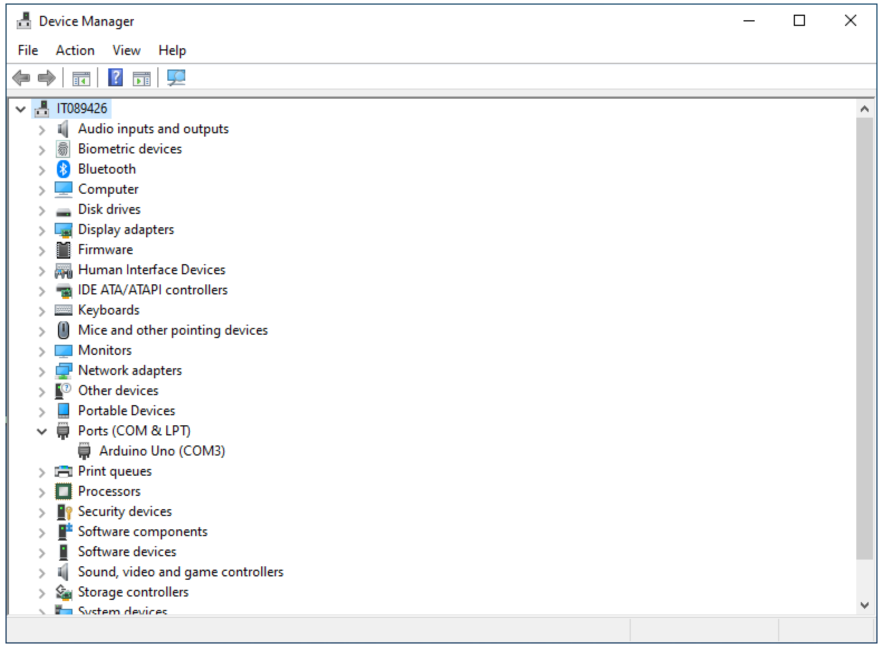
Note: Replace `%USER%` with your username.

Connect an Arduino to your computer.

Open the Start menu, type "Device Manager", and press `Enter`. This will display Windows' Device Manager.

Expand the "Ports" menu to view the Arduino's COM port.

Something similar to the following will be displayed:



- IT089426
  - Audio inputs and outputs
  - Biometric devices
  - Bluetooth
  - Computer
  - Disk drives
  - Display adapters
  - Firmware
  - Human Interface Devices
  - IDE ATA/ATAPI controllers
  - Keyboards
  - Mice and other pointing devices
  - Monitors
  - Network adapters
  - Other devices
  - Portable Devices
  - Ports (COM & LPT)
    - Arduino Uno (COM3)
  - Print queues
  - Processors
  - Security devices
  - Software components
  - Software devices
  - Sound, video and game controllers
  - Storage controllers
  - System devices

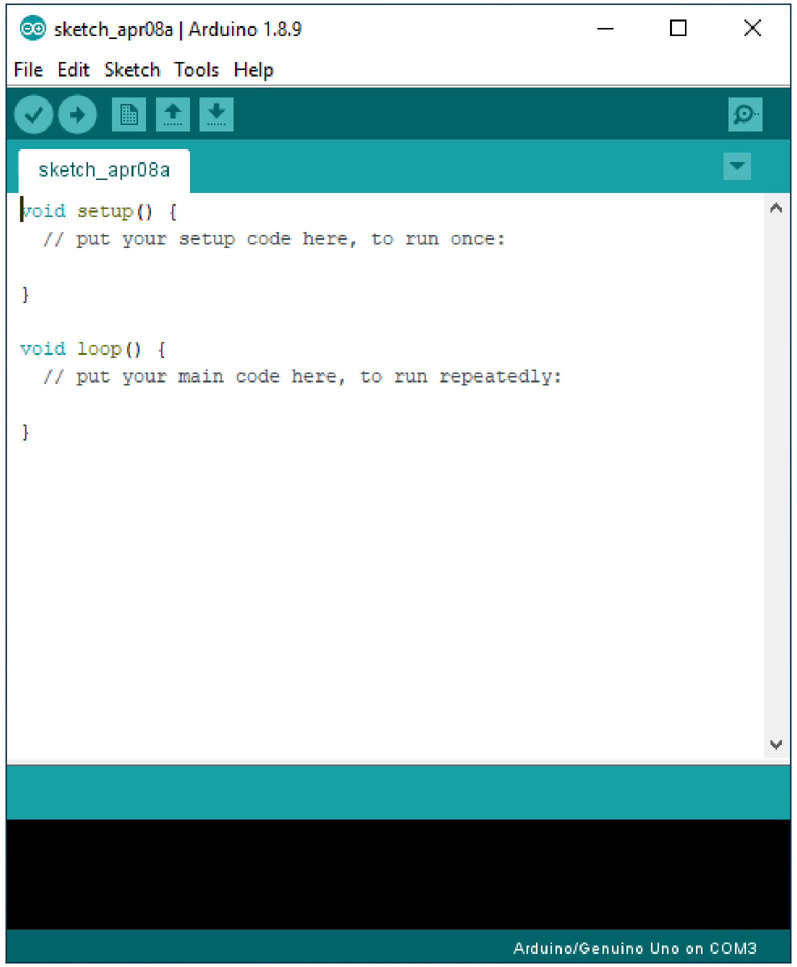
Figure: Windows' Device Manager. Here, an Arduino Uno is connected to the computer. It has enumerated as `COM3`.

Open the Arduino IDE.

Open the Start menu, type "Arduino", and press `Enter`. This will display the Arduino IDE.

Create a new sketch: Select "File > New" or press `Ctrl`+`N`.

Something similar to the following will be displayed:


sketch_apr08a | Arduino 1.8.9
File Edit Sketch Tools Help
sketch_apr08a

```
void setup() {
  // put your setup code here, to run once:

}

void loop() {
  // put your main code here, to run repeatedly:

}
```

Arduino/Genuino Uno on COM3

Figure: Arduino IDE.

Type the following C++ program into the file:

```cpp
void setup()
{
  Serial.begin(9600);

  pinMode(13, OUTPUT);
  digitalWrite(13, HIGH);
}
```

```
void loop()
{
  if (Serial.available() >= 2)
  {
    char buffer[3] {};

    Serial.readBytes(buffer, 3);

    int pin {atoi(buffer)};

    switch(pin)
    {
      case 13:
      {
        digitalWrite(13, !digitalRead(led));
        Serial.println(digitalRead(led));
        break;
      }
    }
  }
}
```

Save the sketch in `C:/Users/%USER%/django_tutorial`: either:

1. Select "File > Save";

   or,

2. Press `Ctrl` + `S`, and navigate to `C:/Users/%USER%/django_tutorial`.

Open Visual Studio Code in `C:/Users/%USER%/django_tutorial`: either:

1. Open Visual Studio Code and select "File > Open Folder..." and navigate to `C:/Users/%USER%/django_tutorial`;
   or,
2. Right click in `C:/Users/%USER%/django_tutorial` and select "Open with Code".

Open a new terminal: either:

1. press `Ctrl`+`~`;
   or
2. select "View > Terminal".

Create a new virtual environment named "venv".

Type the following command into the terminal and then press `Enter`:

```
python -m venv venv
```

This will create the `venv` virtual environment in `django_tutorial`.

Note: A prompt indicating Visual Studio Code "noticed a new virtual environment" and will ask "if you want to select it for the workspace folder". Press the "Yes" button.

Activate the virtual environment.

Type the following command into the terminal and then press `Enter`:

```
.\venv\Scripts\Activate.ps1
```

This will activate the `venv` virtual environment.

Note: To deactivate the `venv` virtual environment, type `deactivate` into the terminal and then press `Enter`.

Install `Django`.

Type the following command into the terminal and then press `Enter`:

```
python -m pip install Django
```

This will install the latest version of `Django` into the `venv` virtual environment.

Install `pyserial`.

Type the following command into the terminal and then press `Enter`:

```
python -m pip install pyserial
```

This will install the latest version of `pyserial` into the `venv` virtual environment.

Update `pip`.

Type the following command into the terminal and then press `Enter`:

```
python -m pip install --upgrade pip
```

This will update `pip` to the latest version.

Creating a project

Create a new project named `web_controller`.

Type the following command into the terminal and then press `Enter`:

```
django-admin startproject web_controller
```

This will create a `web_controller` directory.

`web_controller` contains the following directories and files:

```
web_controller/
    web_controller/
        __init__.py
        asgi.py
        settings.py
        urls.py
        wsgi.py
    manage.py
```

- The outer `web_controller/` root directory is a container for your project.
- `manage.py`: A command-line utility that lets you interact with this Django project in various ways.
- The inner `web_controller/` directory is the actual Python package for your project.
- `web_controller/__init__.py`: An empty file that tells Python that this directory should be considered a Python package.
- `web_controller/settings.py`: Settings/configuration for this Django project.
- `web_controller/urls.py`: The URL declarations for this Django project.
- `web_controller/asgi.py`: An entry-point for ASGI-compatible web servers to serve your project.
- `web_controller/wsgi.py`: An entry-point for WSGI-compatible web servers to serve your project.

The development server

Verify the project works.

Type the following command into the terminal and then press `Enter`:

```
cd web_controller
```

This will change the current directory to the outer `web_controller` directory.

Type the following command into the terminal and then press `Enter`:

```
python manage.py runserver
```

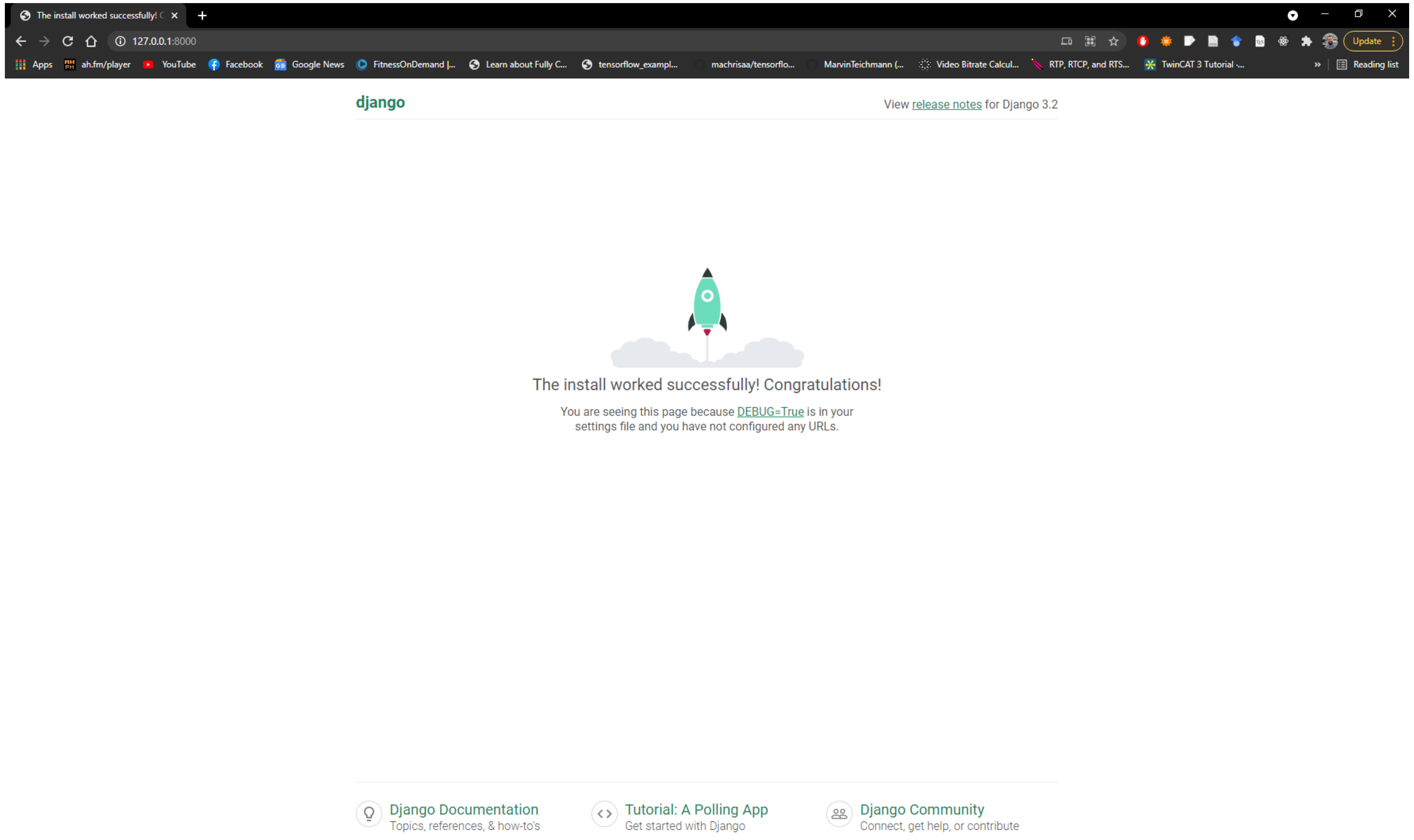
This will launch the development server.

Something similar to the following will be displayed:

```
Watching for file changes with StatReloader
Performing system checks...

System check identified no issues (0 silenced).

You have 18 unapplied migration(s). Your project may not work properly until you apply
    the migrations for app(s): admin, auth, contenttypes, sessions.
Run 'python manage.py migrate' to apply them.
April 07, 2021 - 15:25:44
Django version 3.2, using settings 'web_controller.settings'
Starting development server at http://127.0.0.1:8000/
Quit the server with CTRL-BREAK.
```

Browse to http://127.0.0.1:8000/.

Something similar to the following will be displayed:


django

View release notes for Django 3.2

The install worked successfully! Congratulations!

You are seeing this page because DEBUG=True is in your settings file and you have not configured any URLs.

Figure: The "The Install Worked Successfully! Congratulations" website.

Creating the App app

Create an app named "app".

Type the following command into the terminal and then press `Enter`:

```
python manage.py startapp app
```

This will create an `app` directory.

`app` contains the following directories and files:

```
app/
    migrations/
        __init__.py
    __init__.py
    admin.py
    apps.py
    models.py
    tests.py
    views.py
```

- The `migrations/` directory is where changes to the project's database are stored.
- `migrations/__init__.py`: An empty file that tells Python that this directory should be considered a Python package.
- `__init__.py`: An empty file that tells Python that this directory should be considered a Python package.
- `admin.py`: A file where the app's models are registered.
- `apps.py`: A configuration file for the app.
- `models.py`: A file where the app's models are defined.
- `tests.py`: A file where the app's tests are defined.
- `views.py`: A file where the app's views are defined.

Writing a view

Open `app/views.py` and type the following Python code into the file:

```python
from django.http import HttpResponse


def index(request):
    return HttpResponse("Hello world!")
```

`index()` will display `Hello World!` in the browser when called.

To call the view, we need to map it to a URL.

Create a new file named `urls.py` in `app/`.

Open `app/urls.py` and type the following Python code into the file:

```python
from django.urls import path

from . import views

urlpatterns = [
    path('', views.index, name='index'),
]
```

`index()` is mapped to app's `''` URL.

To access the URL, we need to add it to `web_controller`'s list of URLs.

Open `web_controller/urls.py` and add the following Python code into the file:

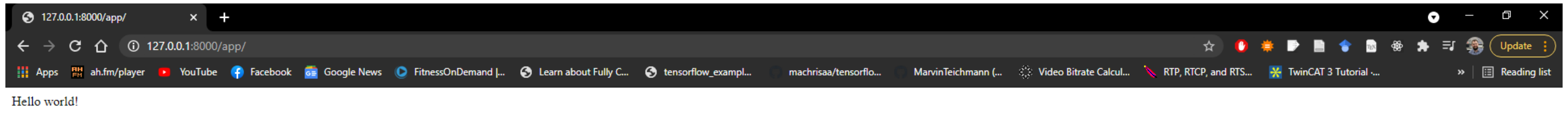
```python
from django.contrib import admin
from django.urls import include, path

urlpatterns = [
    path('app/', include('app.urls')),
    path('admin/', admin.site.urls),
]
```

This will map `index()` to `web_controller`'s `app/` URL.

When browsing to `app/`, `Hello World!` will be displayed.

To view `index()` 's output, browse to http://127.0.0.1:8000/app.

The following will be displayed:



Hello world!

Figure: The `index()` view's output being displayed in the browser.

Database setup

Type the following command into the terminal and then press `Enter`:

```
python manage.py migrate
```

This will create any necessary database tables.

Creating models

A model is a definition of your data's structure; it contains essential fields and behaviours.

Open `app/models.py` and type the following Python code into the file:

```python
from django.db import models


class PIN(models.Model):
    id = models.AutoField(primary_key=True)
    name = models.CharField(max_length=200, default='13')
    pin_number = models.IntegerField(default=13)
    state = models.BooleanField(default=0)

    def __str__(self):
        return self.name
```

Activating models

Open `web_controller/settings.py` and type the following Python code into the file:

```
...
INSTALLED_APPS = [
    'app.apps.AppConfig',
    'django.contrib.admin',
    'django.contrib.auth',
    'django.contrib.contenttypes',
    'django.contrib.sessions',
    'django.contrib.messages',
    'django.contrib.staticfiles',
]
...
```

Type the following command into the terminal and then press `Enter`:

```
python manage.py makemigrations
```

This will save any changes that have been made to the project's models.

Something similar to the following will be displayed:

```
Migrations for 'app':
  app/migrations/0001_initial.py
    - Create model PIN
```

The migration will be saved in `app/migrations`.

Type the following command into the terminal and then press `Enter`:

```
python manage.py check
```

This will check if there are any issues with the project.

Something similar to the following will be displayed:

```
System check identified no issues (0 silenced).
```

Type the following command into the terminal and then press `Enter`:

```
python manage.py migrate
```

This will apply any changes that have been made to the project's database.

Something similar to the following will be displayed:

```
Operations to perform:
  Apply all migrations: admin, auth, contenttypes, app, sessions
Running migrations:
  Rendering model states... DONE
  Applying app.0001_initial... OK
```

The database API

Type the following command into the terminal and then press `Enter`:

```
python manage.py shell
```

This will invoke the Python shell.

Type the following commands into the Python shell:

```
>>> from app.models import PIN
>>> PIN.objects.all()
<QuerySet []>
>>> pin = PIN(name="13", pin_number=13, state=False)
>>> pin.save()
>>> pin.id
1
>>> pin.name
'13'
>>> pin.pin_number
13
>>> pin.state
False
>>> pin.state = True
>>> PIN.objects.all()
<QuerySet [<PIN: 13>]>
>>>
```

Press `Ctrl`+`Z` and then `Enter` to terminate the shell.

The Django admin

Type the following command into the terminal and then press `Enter`:

```
python manage.py createsuperuser
```

Enter a username, email, and password.

Note: If your password is too similar to the username, too short (< 8 characters), or too common, you will receive a warning message. However, you can bypass password validation if you want.

Open `app/admin.py` and type the following Python code into the file:

```python
from django.contrib import admin

from .models import PIN


admin.site.register(PIN)
```

This will register the `PIN` model with the Django admin website.

To view the admin website, browse to http://127.0.0.1:8000/admin.

The following will be displayed:

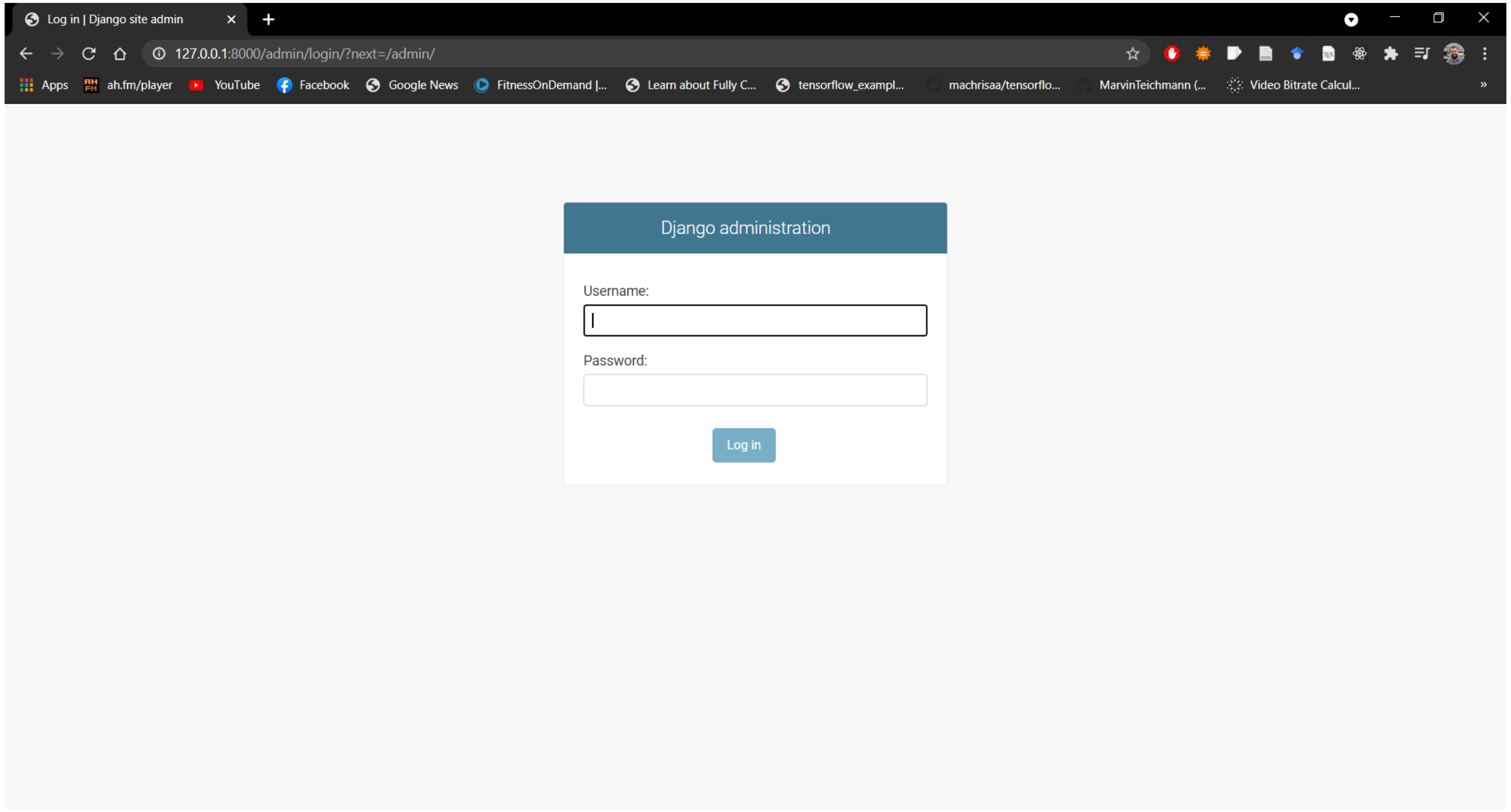
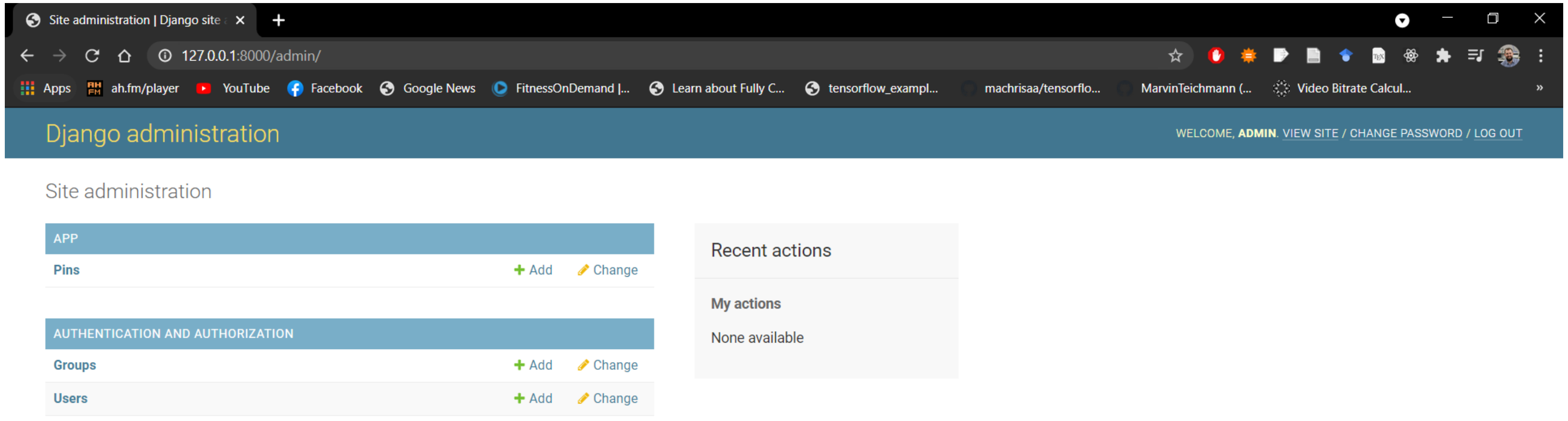


Figure: Django admin website.

Log in with the admin user's credentials.

The following will be displayed:


Django administration

WELCOME, ADMIN. VIEW SITE / CHANGE PASSWORD / LOG OUT

Site administration

APP		
Pins	+ Add	Change

AUTHENTICATION AND AUTHORIZATION		
Groups	+ Add	Change
Users	+ Add	Change

Recent actions

My actions

None available

Figure: Django admin website.

Left click on the "Pins" link.

The following will be displayed:

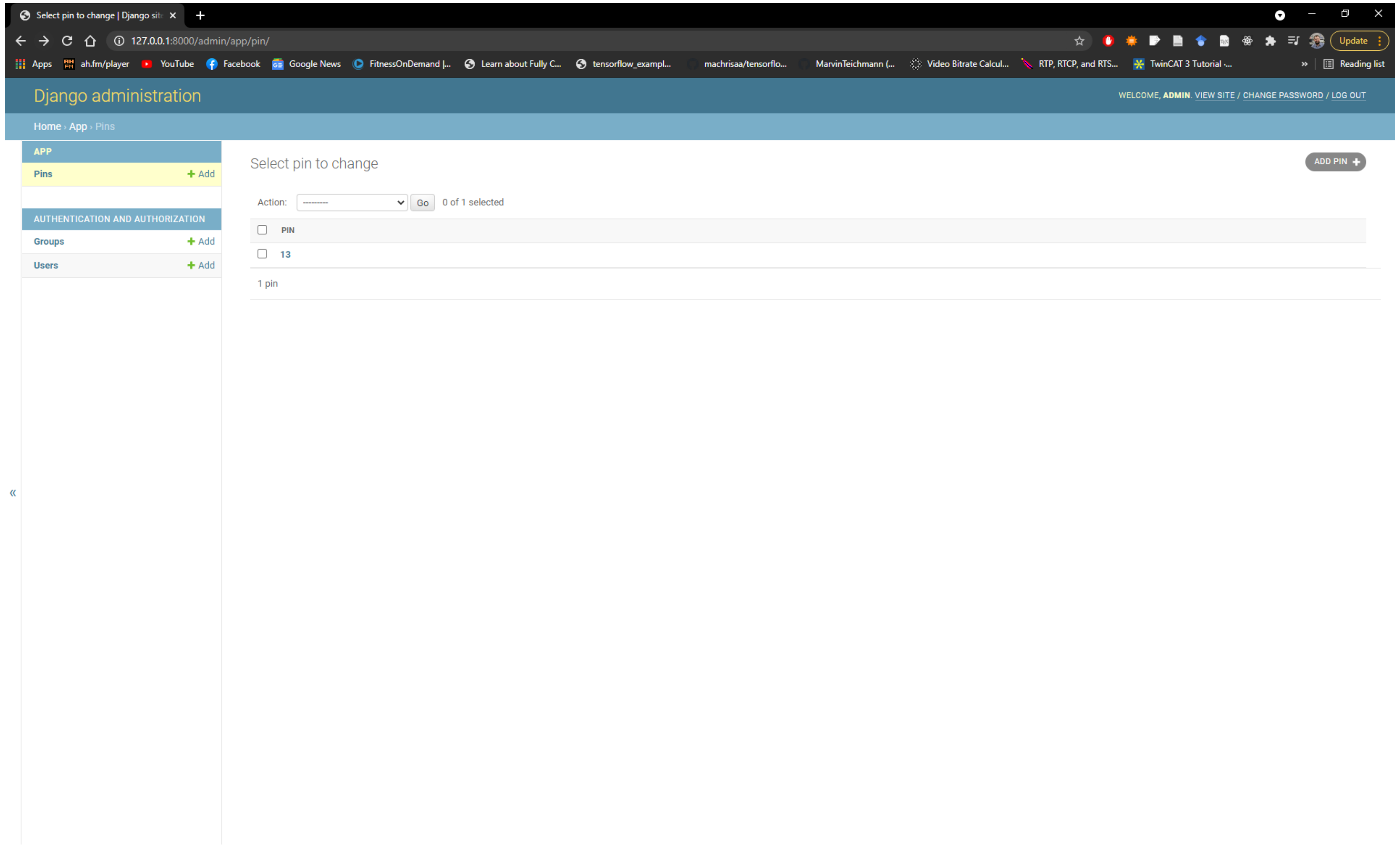
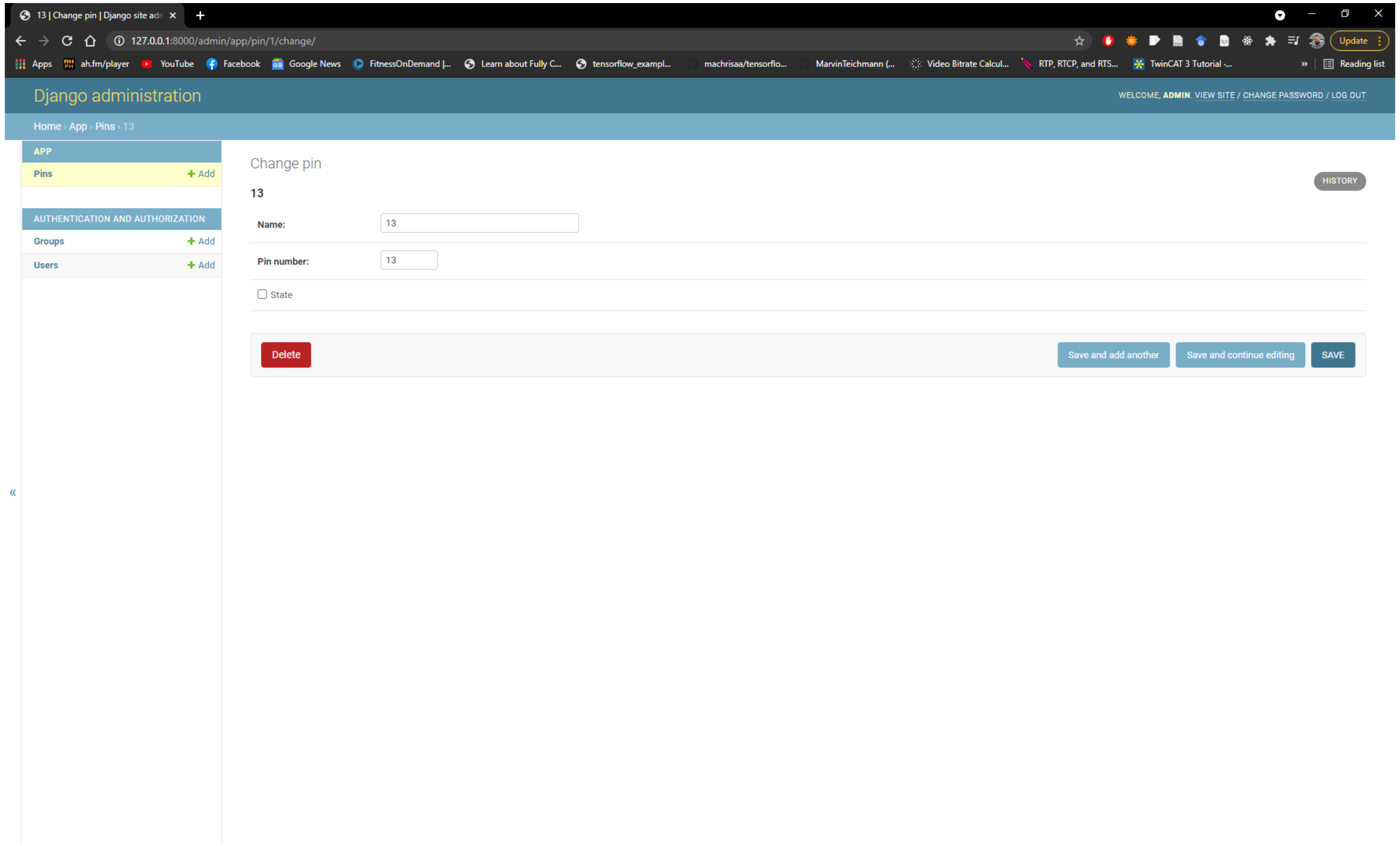

Django administration
WELCOME, ADMIN. VIEW SITE / CHANGE PASSWORD / LOG OUT
Home › App › Pins
APP
Pins + Add
AUTHENTICATION AND AUTHORIZATION
Groups + Add
Users + Add
Select pin to change
ADD PIN +
Action: --------- Go 0 of 1 selected
PIN
13
1 pin

Figure: Django admin website.

Left click on the "13" link.

The following will be displayed:



Change pin

13

Name:	13
Pin number:	13
☐ State	

Figure: Django admin website.

Writing more views

Open `app/views.py` and type the following Python code into the file:

```python
from django.http import HttpResponse


def index(request):
    return HttpResponse("Hello world!")


def toggle(request, pin_number):
    return HttpResponse("pin_number: {}".format(pin_number))
```

`toggle()` accepts an additional argument, `pin_number` and will display its value in the browser when called.

To call the view, we need to map it to a URL.

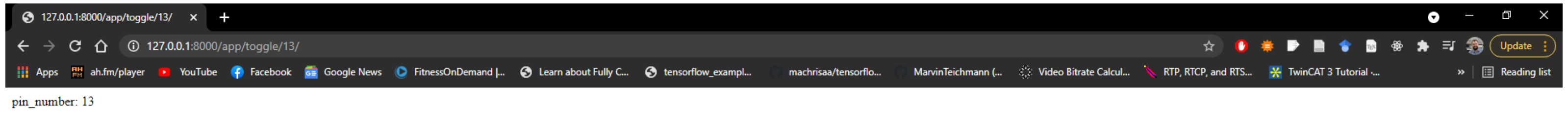
Open `app/urls.py` and type the following Python code into the file:

```python
from django.urls import path

from . import views

urlpatterns = [
    path('', views.index, name='index'),
    path('toggle/<int:pin_number>/', views.toggle, name='toggle')
]
```

`toggle()` is mapped to app's `'toggle/<int:pin_number>/'` URL.

To view `toggle()`'s output, browse to http://127.0.0.1:8000/app/toggle/13/.

The following will be displayed:



```
pin_number: 13
```

Figure: The `toggle()` view's output being displayed in the browser.

Write views to do something

Open `app/views.py` and type the following Python code into the file:

```python
from django.htpp import HttpResponse

from .models import PIN

def index(request):
    pin_list = PIN.objects.order_by('name')[:]

    output = ','.join([p.name for p in pin_list])

    return HttpResponse(output)
...
```

`index()` get's a list of all the `PIN` instances and displays it in the browser.

The problem with this is that the page's design is hard-coded in the view.

Create a a new directory named "templates" in `app`.

Create a new directory named "app" in `app/templates/`.

Create a new file named "index.html" in `app/templates/app`.

Open `app/index.html` and type the following HTML code into file:

```
<!doctype html>
<html lang="en">
  <head>
    <meta charset="utf-8">
    <title>Pin Toggle</title>
  </head>
  <body>
    {% if pin_list %}
        <table>
        {% for pin in pin_list %}
            <tr><td>{{pin.name}}[{{pin.number}}] is {{pin.state}}</td></tr>
            <button value="{{pin.pin_number}}">Click me!</button>
        {% endfor %}
        </table>
    {% else %}
        <p>No pins are available.</p>
    {% endif %}
  </body>
</html>
```

Open `app/views.py` and type the following Python code into the file:

```
from django.http import HttpResponse
from django.template import loader

from .models import PIN

def index(request):
    pin_list = PIN.objects.order_by('name')[:]

    template = loader.get_template('app/index.html')
    context = { 'pin_list': pin_list }

    return HttpResponse(template.render(context, request))
...
```

`index()` get's a list of all the `PIN` instances and displays it in the browser.

This time, a template is used to decouple the page's design and the view.

A shortcut: `render()`

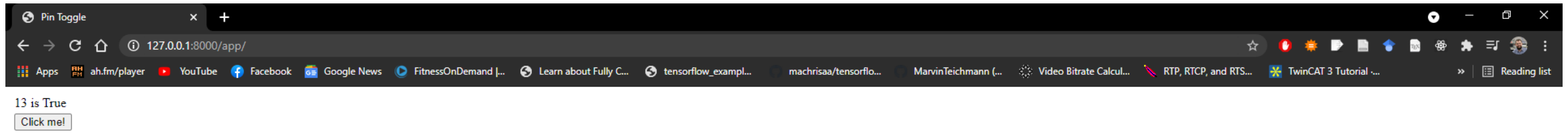
Open `app/views.py` and type the following Python code into the file:

```python
from django.shortcuts import render

from .models import PIN

def index(request):
    pin_list = PIN.objects.order_by('name')[:]

    context = {'pin_list': pin_list}

    return render(request, 'app/index.html', context)
...
```

`render()` is a shortcut used to display templates.

To view `index()` 's output, browse to http://127.0.0.1:8000/app/.

The following will be displayed:



```
13 is True
```

Figure: The `index()` view's output being displayed in the browser.

Using static files

Create a a new directory named "static" in `app`.

Create a new directory named "app" in `app/static/`.

Create new files named "index.css" and "index.js" in `app/static/app`.

Browse to https://jquery.com/ and download jQuery (3.6 as of 04/21).

Download the "uncompressed, development JQuery" file.

Save the downloaded file in `static/app`.

Open `web_controller/settings.py` and type the following Python code into the file:

```
...
STATICFILES_DIRS = [
    BASE_DIR / "static/",
]
...
```

Open `app/index.js` and type the following JavaScript code into the file:

```javascript
function getCookie(name) {
    let cookieValue = null;
    if (document.cookie && document.cookie !== '') {
        const cookies = document.cookie.split(';');
        for (let i = 0; i < cookies.length; i++) {
            const cookie = cookies[i].trim();
            // Does this cookie string begin with the name we want?
            if (cookie.substring(0, name.length + 1) === (name + '=')) {
                cookieValue = decodeURIComponent(cookie.substring(name.length + 1));
                break;
            }
        }
    }
    return cookieValue;
}

const csrftoken = getCookie('csrftoken');
```

```
$('button').click(function () {
    console.log(this.id + ' ' + 'clicked!');

    $.ajax({
        type: 'POST',
        url: '/app/toggle/' + this.value + '/',
        data: {
            'pin_number': this.value,
        },
        headers: {
            'X-CSRFToken': csrftoken
        },
        success: function() {
            console.log('Success');
        },
        dataType: 'text'
    })
});
```

Open `app/index.html` and type the following HTML code into the file:

```
...
<body>
    ...
    {% load static %}

    <link rel="stylesheet" type="text/css" href="{% static 'app/index.css' %}">
    <script type="text/javascript" src="{% static 'app/jquery-3.6.0.js' %}"></script>
    <script type="text/javascript" src="{% static 'app/index.js' %}"></script>
</body>
...
```

Writing to a serial port

Open `app/views.py` and type the following Python code into the file:

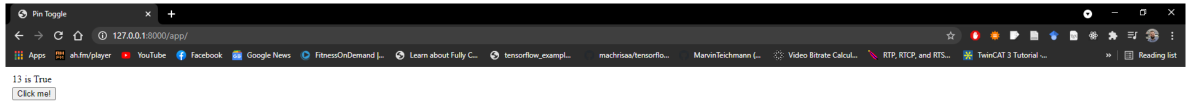
```python
import serial

from django.shortcuts import render

from .models import PIN


ser = serial.Serial('COM3')


def toggle_pin(pin=13):

    ser.write('{}\n'.format(pin).encode('utf-8'))

    return 0
```

```python
def index(request):
    pin_list = PIN.objects.order_by('name')[:]
    context = {'pin_list': pin_list}

    return render(request, 'app/index.html', context)


def toggle(request, pin_number):
    pin = PIN.objects.get(pin_number=pin_number)
    pin.state = False if pin.state is True else True
    pin.save()

    toggle_pin(pin.pin_number)

    pin_list = PIN.objects.order_by('name')[:]
    context = {'pin_list': pin_list}

    return render(request, 'app/index.html', context)
```

Testing

To test the setup, browse to http://127.0.0.1:8000/app/.

Something similar to the following will be displayed:



13 is True

Figure: (Left) The "Pin Toggle" website; and (Right) the Arduino plugged into the computer. Here, we can see that the website indicates the Arduino's Pin 13 is HIGH (True); the LED connected to Pin 13 is ON.

Left click on the "Click Me!" button.

Something similar to the following will be displayed:

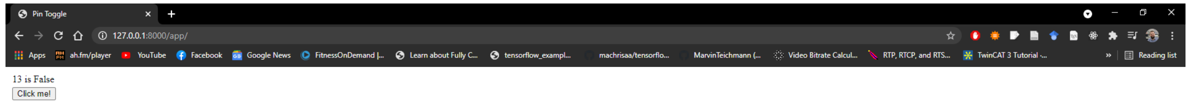

13 is False

Figure: (Left) The "Pin Toggle" website; and (Right) the Arduino plugged into the computer. Here, we can see that the website indicates the Arduino's Pin 13 is LOW (False); the LED connected to Pin 13 is OFF.

The LED has been turned off via a website!

Conclusion

In this presentation, I have described:

- How to control an Arduino's pin via the web using the Django web framework.

References

1. https://www.djangoproject.com/
2. https://www.djangoproject.com/start/
3. https://docs.djangoproject.com/en/3.2/intro/tutorial01/
4. https://jquery.com/
5. https://getbootstrap.com/
6. https://docs.djangoproject.com/en/3.1/ref/csrf/
7. https://www.w3schools.com/html/
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9. https://www.digitalocean.com/community/tutorials/how-to-set-up-django-with-postgres-nginx-and-gunicorn-on-ubuntu-20-04