Ethereum Smart contracts development

With Javascript (2020)

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Part 3
Truffle framework

A framework for the development of smart contracts

Walkthrough

1. Introduce the Truffle framework
2. Init a new Truffle project
    a. Project structure
    b. Configuration file
3. Development
    a. Coding
    b. Compiling
    c. Testing
    d. Migrating

1. The Truffle Framework

Truffle is a CLI framework providing developers sweet tools for Ethereum smart contracts development. In particular:

- The Solidity **compiler**;
- A **migration** tool to deploy contracts to an Ethereum network;
- A **testing** environment;

- A NodeJs **console** to interact with the migrated contracts;
- An **execution** tool to automate commands inserted in the console

1. Installing Truffle

Truffle can be installed with npm

Requirements: NodeJs (v8.9.4 or later) and npm

Truffle, global installation:

```
$ (sudo) npm install -g truffle
```

2. Truffle: create a project

```
$ truffle init
```

Initialize an empty Ethereum project in the current folder structured as:
- contracts/
- migrations/
- test/
- truffle-config.js

2.a. Truffle: contracts/

This folder contains the Solidity smart contracts

By default, it includes a Migration.sol contract used by Truffle. Don’t delete it. I did it once and nothing was working anymore

2.a. Truffle: migrations/

This folder contains Javascript sources that Truffle executes during the migration phase, i.e. when the contracts are deployed to the blockchain

2.a. Truffle: test/

This folder contains Javascript sources to test the smart contracts

Truffle uses the Mocha testing framework, and the Chai assertion library

- Extra assertion commands are provided by **truffle-assertions** npm package
  - Test events and require() statements
  - https://www.npmjs.com/package/truffle-assertions

2.b. Truffle: truffle-config.js

This is Truffle configuration file, it tells Truffle which network to target, the Solidity compiler, and other settings

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Example of a local network:

```
 networks: {
   development: {          // Network name
    host: "127.0.0.1",     // Localhost (default: none)
    port: 7545,            // Standard Ethereum port (default: none)
    network_id: "*",       // Any network for local (default: none)
   },
}
```

3. Development with Truffle

A typical workflow to develop smart contracts includes coding, testing and, when the contract is complete, migrate (deploy) it to a target network

Truffle simplifies the steps mentioned above, but we need to tell Truffle how to accomplish them

But first, we need a smart contract to work with

3.a. Example contract

```
// ./contracts/MyContract.sol
contract MyContract {
    uint public value;

    constructor() public {
        value = 1;
    }
    function increase(uint _v) public {
        value = value + _v;
    }
    function get_square() public view returns (uint) {
        return value * value;
    }
}
```

3.b. Truffle: compilation

We store our contract in the *contracts/* folder

We can compile the smart contract(s) in the *contracts/* folder with the following command:

```
$ truffle compile
```

It creates the *build/* folder with the results of the compilation in .json format, including the ABI (Abstract Binary Interface) and the bytecode

3.c. Truffle: testing

How can we execute a smart contract?
Well, smart contracts are executed by the nodes of the Ethereum network

We can instead use a local network (blockchain)

- Create one on the fly while running the tests
  - Solution adopted now (no configs are needed)
- Have one running in the background
  - More on that on the “Migration” slides

3.c. Truffle: testing

A testing file requires to:

- Create a file *test_mycontract.js* inside the *test/* folder
- Import the compiled smart contract from the *build/* folder
- Create test environments
- Code testing scripts
    - Web3 calls to smart contract functions are **asynchronous**, which are implemented by **Promise** objects in Javascript

3.c. Truffle: testing

```
// ./test/test_mycontract.js
// Import the contracts to test in Truffle from build/
   // MyContract is a template, not an instance (e.g. the Class, not the object)
const MyContract = artifacts.require("MyContract"); // ./build/MyContract.json
// Create a testing environment
// accounts are Ethereum accounts, injected by Truffle. More on that later
contract("Testing MyContract", accounts => {
   // Create a test
   it("Should test the constructor", function() {
       // 1 Create a known state
       // 2 Execute the operation to test
       // 3 Test the conditions
   }); });
```

3.c. Javascript promises

When you call a smart contract function with Web3 you get as result a Javascript Promise object:

- *const promise = contract.function_name(params);*

When a Promise is completed, we can use its result within the *then* statement:

- *promise.then((result) => {// use your result here})*

More on [Javscript Promises]

3.c. Truffle: testing

```
// ./test/test_mycontract.js
   it("Should test the constructor", function() {
       // 1 Create a known state: not here, we test the constructor
       // 2 Execute the operation to test, i.e. the constructor
       return MyContract.new() // Create a new contract
           .then(instance => {
               // “instance” is a constructed instance of MyContract
               // 3 Test the condition: i.e. if value is 1
               return instance.value().then(v => {
                   // “v” is the result of value(): solidity uint256 are BigNumber objets
                   assert.equal(v.toNumber(), 1, "Value should be initialized at 1");
               });
           }); // end return MyContract.new }); // end it()
```

3.c. Truffle: testing with async/await

To lighten the code it is possible to use the **async / await** syntax. This results to a complete synchronous code, but it is enough for our goals that do not require heavy asynchronous programming

```
it("Should test the constructor with async/await", async function() {
    // 1 Create a known state: not here, we test the constructor
    // 2 Execute the operation to test, i.e. the constructor
    const instance = await MyContract.new();
    // 3 Test the condition: i.e. if value is 1
    const v = await instance.value();
    assert.equal(v.toNumber(), 1, "Value should be initialized at 1");
});
```

3.c. Truffle: testing

After a test has been written:

- Execute all the test files inside test/ folder with:
  ```
  $ truffle test
  ```

- Execute a single test file inside test/
  ```
  $ truffle test test/test_mycontract.js
  ```

3.c. Smart contract return values

When executed with Web3, functions which are labeled as **view / pure** return the value of the Solidity return statement. Such functions won't be put in a block (mined) and they do not cost a fee to the caller

However, the other functions are so called **transactions**, meaning that they will be mined, put in a block and they do cost a fee. When executed their return value IS NOT the value expressed by the Solidity return statement, but a **transaction**

3.c. Our contract (modified)

```
contract MyContract {

   uint public value;

   constructor() public {
       value = 1;
   }
   function increase(uint _v) public returns (uint) {
       value = value + _v;
       return value; // new
   }
   function get_square() public view returns (uint) {
       return value * value;
   } }
```

3.c. Truffle: testing transactions

The *assert.equal()* condition should **fail** because *result* is not the integer as expected by the Solidity code, but it is an object, i.e. the transaction with information like block number, gas used etc...

```
it("Should increase the value by 41", async function() {
    // 1 Create a known state
    const instance = await MyContract.new();
    // 2 Execute the operation to test
    const result = await instance.increase(41);
    // 3 Test the condition
    assert.equal(result.toNumber(), 42, "The result should be 42");
});
```

3.c. A transaction receipt

```
File  Edit  View  Search  Terminal  Help

  Contract: MyContract
    ✓ Should test the constructor (62ms)
    ✓ Should test the constructor with async/await (75ms)
{
  tx: '0x1a2212f8a7e9ff02342853639c3043c830546bbe50b2deccd3dc884cde074458',
  receipt: {
    transactionHash: '0x1a2212f8a7e9ff02342853639c3043c830546bbe50b2deccd3dc884cde074458',
    transactionIndex: 0,
    blockHash: '0xc200e098b21085285b4740934494fd07ee1695cdc44360962be453b8429fd343',
    blockNumber: 6,
    from: '0x627306090abab3a6e1400e9345bc60c78a8bef57',
    to: '0x8f0483125fcb9aaaefa9209d8e9d7b9c8b9fb90f',
    gasUsed: 28102,
    cumulativeGasUsed: 28102,
    contractAddress: null,
    logs: [],
    status: true,
    logsBloom: '0x00000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000',
    rawLogs: []
  },
  logs: []
}
    ✓ Should increase the value by 41 (76ms)
```

3.c. Smart contract return values

How can I get the return value of a transaction?

Ideas:

- Emit an event, with the result the argument of the event
    - Events and their data are contained in the **logs** field of the transaction object
- Call a view function right after the transaction (free of gas)

More information on

https://truffleframework.com/docs/truffle/getting-started/interacting-with-your-contracts

3.c. Smart contract return values

Warning

This holds when using the Web3 wrapper

If another smart contract calls the *increase()* function gets the return value as expected

3.c. Truffle: testing, conclusions

Testing smart contracts with Truffle can be tricky at the beginning , but it is very straightforward once understood how it works

Visit the Mocha and Chai pages for documentations

So far we have seen how to test smart contracts without providing any network (blockchain)

3.d. Truffle: migrating

As soon we feel confident of our contracts we can migrate (deploy) them to a target network

To migrate our contracts we need to:

- Write in our *truffle_config.js* file the target network settings
- Write our migration script
  - In this script we decide which contracts we migrate
- Execute the migration script with the command provided by Truffle

3.d. Truffle: migrating

We can start with a local (simulated) network for the development

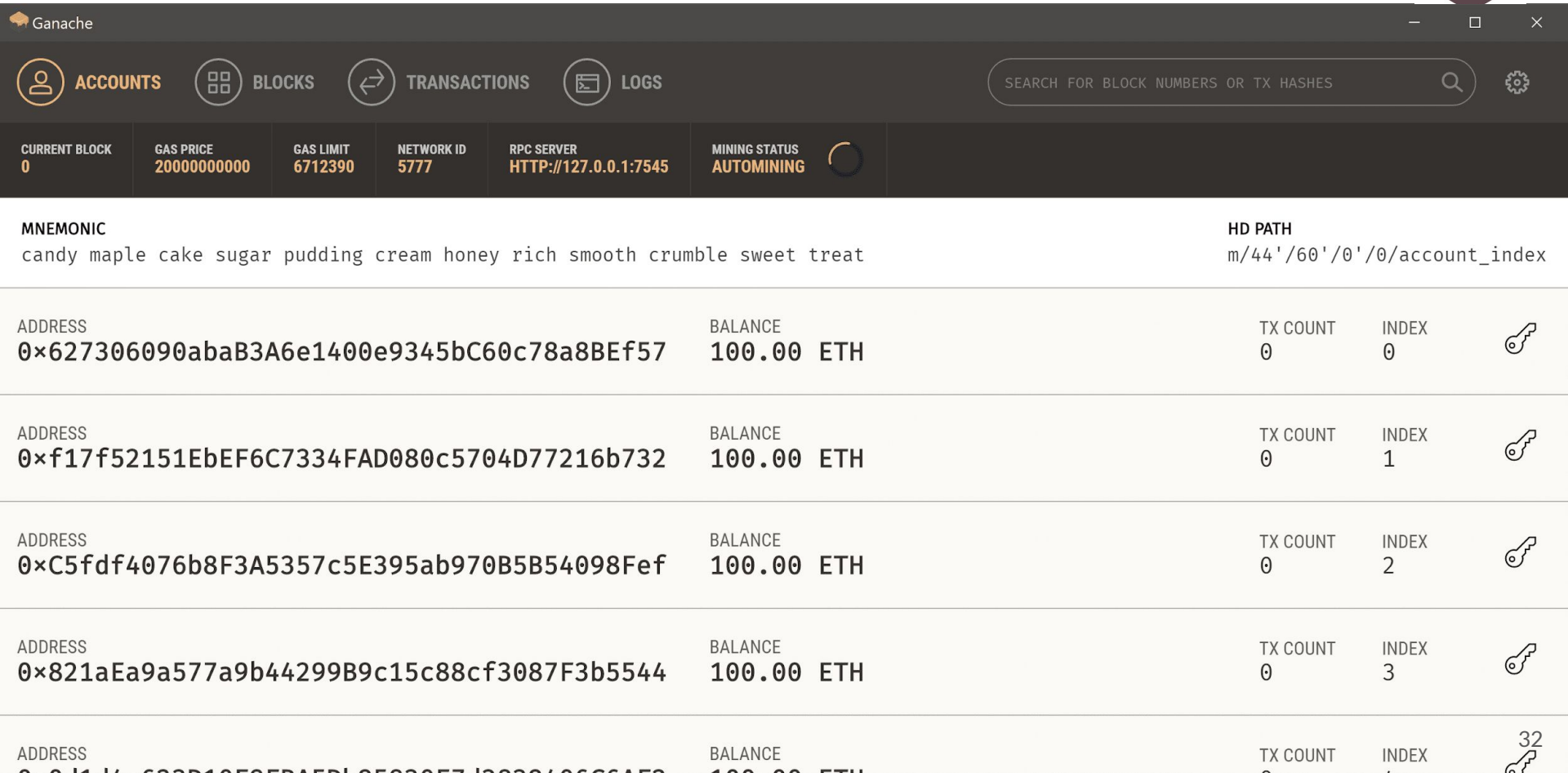
The Truffle suite provides Ganache

- The CLI version: https://github.com/trufflesuite/ganache-cli
- The GUI version: https://www.trufflesuite.com/ganache

Ganache CLI, how it looks like

```
File  Edit  View  Search  Terminal  Help
alic@0alic:~/Documents/PHD/SupportP2P2020/lezioni/example$ ganache-cli
Ganache CLI v6.5.0 (ganache-core: 2.6.0)

Available Accounts
==================
(0) 0x015cc24d96037a9130acdfcd113f3dad398273ca (~100 ETH)
(1) 0x183834fcc483997b53cf5fd644c96fc6110d7f0c (~100 ETH)
(2) 0xd1d9e7382ba1a0a10fc77499715937d234a57550 (~100 ETH)
(3) 0x3a0b1a43dae7c66a59b29427bc4fbe7b106f4b6e (~100 ETH)
(4) 0x0eb8274f5a09c933a5fa8b793c9feac19b1d6e2c (~100 ETH)
(5) 0x27a19ff14eb9a29ec800254b42849fa4135b50a3 (~100 ETH)
(6) 0x2886f438aa9d2594843618b721b6c1741871e91b (~100 ETH)
(7) 0x08bf94b966897fb2a3d0212104b2eba30fb470f6 (~100 ETH)
(8) 0xb9f97e6baa0a22cb7387adbe1f330a5aec6b95aa (~100 ETH)
(9) 0x4b4db6b8101ca0a8352664f72d7e8ede941b6dc1 (~100 ETH)

Private Keys
==================
(0) 0x59ec464379dfc2c0b67da8d55657ca5be653b16ac98ffe07094631322c84b489
(1) 0x32b07708eee00e9086e0718d05b92d55e749c081b88f3c01b1143c812701eeeb
(2) 0x69684baefb82b558a959752c9f405cb2d018fb15e3910333cf3e21475fbbb8ff
(3) 0x7b6294a1aa37ecd8c996ff4224646a9455d22b71f2c2165e0578756cde2f307c
(4) 0x0af8fa44d16c95fd83c01f1b0d7173d3d7740c69e02d804495c5340fa859d67e
(5) 0x21f3a73c9369fdd4939ea22e03a49d6c227328308bbf6cca1580df5b1a327c78
(6) 0xb3f26374bf86a81ab5efa6a9a483b34ae84497db17f1a979af05f8ca0783abad
(7) 0xf94e23db254fe7bebfe08dceba7839a6279da04dc73116864ce4bf120414b244
(8) 0xbe52cffd30b13f0c35d3512f26f763ec3f651f027bb34278c1eab5ba38e5a33c
(9) 0x09469843de48e4e3f3a7d30c148e63d71f203928b167f018b5d3397320fde190

HD Wallet
==================
Mnemonic:      uncover absent point off reduce scorpion world small table reveal wide siren
Base HD Path:  m/44'/60'/0'/0/{account_index}

Gas Price
==================
20000000000

Gas Limit
==================
6721975

Listening on 127.0.0.1:8545
```

Ganache GUI, how it looks like



3.d. Truffle: migrating, config

We need to tell Truffle to target our Ganache network

In our configuration file *truffle_config.js*:

- We create an identifier for our **network** called “development”
- Ganache **host** is local host, i.e. “127.0.0.1”
- Ganache **port** can be set, assuming “8545”
- In this case **network_id** can be anything, represented with “*”

During initialization Truffle creates a pre-compiled config file, all commented. Therefore we need only to un-comment the interested portion

3.d. Truffle: migrating, config

development is a special name for a network. When targeting a network with a Truffle command “development” can be omitted

The fields in *truffle_config.js* are shown below:

```
 networks: {
   development: {          // Network name
    host: "127.0.0.1",     // Localhost (default: none)
    port: 8545,            // Ethereum port (default: none)
    network_id: "*",       // Any network for local (default: none)
   },
}
```

3.d. Truffle: migrating, scripts

The migration scripts are placed in the *migrations/* folder

Truffle executes the scripts in that folder using a lexicographic order. Typically these scripts are called *1_***.js*, *2_+++.js*

This folder contains by default the *1_initial_migration.js* script, which migrates the Migration.sol contracts, useful for Truffle

3.d. Truffle: migrating, scripts

The default *1_initial_migrations.js* file:

```
// Import the contracts to migrate from build/
const Migrations = artifacts.require("Migrations"); // ./build/Migrations.json

// The function to execute during the migration
module.exports = function(deployer) {
 // Deploy the Migrations contract, i.e. an instance of Migration on the target network
 // This command executes the constructor. If Migration would have had parameters
 // in its constructor, they should have been as following arguments of deploy()
 deployer.deploy(Migrations);
};
```

3.d. Truffle: migrating

After being sure that Ganache is running, we can execute our scripts in *migrations/* with:

```
$ truffle migrate --reset --network development
```

- *--network net* specifies the target network named *net*
  - *development* is the default one, therefore the *--network development* option can be omitted
- Truffle does not re-migrate up-to-date contracts
  - *-- reset* forces Truffle to migrate all the contracts
- You should see the balance of the first account decreased by a little

3.d. Truffle: migrating, scripts

We can modify *1_initial_migrations.js* to migrate also our contract:

```
const Migrations = artifacts.require("Migrations");
const MyContract = artifacts.require("MyContract");


module.exports = function(deployer) {
 deployer.deploy(Migrations);
 deployer.deploy(MyContract);
};
```

3.d. Truffle: migrating, scripts

We can get the network name, in case we have many, to filter execution:

```
const Migrations = artifacts.require("Migrations");
const MyContract = artifacts.require("MyContract");

// These inputs are injected by Truffle
module.exports = function(deployer, network) {
 deployer.deploy(Migrations);
 if(network == "development") {
  deployer.deploy(MyContract);
 }
};
```

3.d. Truffle: migrating, scripts

We can get the accounts of our target network:

```
const Migrations = artifacts.require("Migrations");
const MyContract = artifacts.require("MyContract");

// These inputs are injected by Truffle
module.exports = function(deployer, network, accounts) {
 deployer.deploy(Migrations);
 if(network == "development") {
  deployer.deploy(MyContract, {from: accounts[1]}); // Use your second account to deploy
 }
};
```

3.d. Truffle: migrating, scripts

Do not forget that these functions return Promises:

```
const Migrations = artifacts.require("Migrations");
const MyContract = artifacts.require("MyContract");

// These inputs are injected by Truffle
module.exports = async (deployer, network, accounts) => {
 await deployer.deploy(Migrations);
 if(network == "development") {
   const instance = await deployer.deploy(Migrations, {from: accounts[2]});
   // Do stuff with instance...
 }};
```

3.d. Truffle: migrating, conclusions

Migrating means deploying a contract to a target network. This network is specified in the *truffle_config.js* file

An example of local network is Ganache

3.d. Truffle: migrating, conclusions

Warning

When exposing the “development” network the “on the fly” blockchain as explained in *3.c. Truffle: testing* does not work anymore, and if the target network is not running Truffle will complain

This because omitting the *--network* flag Truffle uses “development” by default, **if exposed**

Truffle: conclusions

Truffle eases the workflow to develop, test and migrate smart contracts

The suite provides other tools we didn't see, like its console and a way to execute scripts within the Truffle environment

- Type `$ truffle help` to see the list of available cmds

If the smart contracts are small, and few checks are required, then Remix is enough

Truffle: conclusions

Installing Truffle you install also the Solidity compiler and Web3Js

During the execution of Truffle cmds Web3Js injected by Truffle, and so there is no need to import the library

But many examples with Truffle use the Web3 wrapper **truffle-contract**

- It makes calling smart contract functions more intuitive
- All the examples in the Truffle page use this wrapper
- https://github.com/trufflesuite/truffle/tree/master/packages/contract

Truffle: docs

Config file: https://truffleframework.com/docs/truffle/reference/configuration

Compilation: https://truffleframework.com/docs/truffle/getting-started/compiling-contracts

Testing with Js: https://truffleframework.com/docs/truffle/testing/writing-tests-in-javascript

Migration: https://truffleframework.com/docs/truffle/getting-started/running-migrations

And online tutorials...

Extra

Other ways to interact with the smart contracts

Retrieve contract instances

How to get an instance of a contract:

- .new(), .deployed() and .at()

```
   it("Should retrieve the instance of a contract", async function() {
       const address = "0x001d3...f1f086ba0f9"; // A contract address
       const _new = await MyContract.new(); // Create a new contract, return the instance
       const last = await MyContract.deployed(); // Get the *last* deployed instance of
MyContract
       const that = await MyContract.at(address); // Get the *deployed* instance of
MyContract of address "address"
   });
```

Transaction parameters

In Solidity we get the special constructs msg.value, msg.sender, etc

- msg.sender is the account invoking the function
- When omitted the default account is [0]

```
it("Should send Ether to a payable function", async function() {

    const instance = await MyContract.new();
    const tx = await instance.foo(41); // default account is accounts[0]
});
```

https://www.trufflesuite.com/docs/truffle/getting-started/interacting-with-your-contracts#making-a-transaction

Transaction parameters

In Solidity we get the special constructs msg.value, msg.sender, etc

- msg.sender is the account invoking the function
- Otherwise it can be specified with a special last-parm object

```
it("Should send Ether to a payable function", async function() {
    const alice = accounts[3];
    const instance = await MyContract.new();
    const tx = await instance.foo(41, {from: alice});
});
```

https://www.trufflesuite.com/docs/truffle/getting-started/interacting-with-your-contracts#making-a-transaction

Transaction parameters

In Solidity we get the special constructs msg.value, msg.sender, etc

- msg.value must be provided, if required
- It is a field of the special object

```
it("Should send Ether to a payable function", async function() {
    const alice = accounts[3];
    const instance = await MyContract.new();
    const tx = await instance.foo(41, {from: alice, value: 10000000}); // wei
});
```

https://www.trufflesuite.com/docs/truffle/getting-started/interacting-with-your-contracts#making-a-transaction

Manual interaction

Truffle provides two Javascript consoles to manually interact with your contracts:

- **Console**: Connects to a network like Ganache (or also the Ethereum main and test networks) and you interact with it
- **Develop**: Similar, but it creates a on-the-fly network
- https://www.trufflesuite.com/docs/truffle/getting-started/using-truffle-develop-and-the-console

Automatic interaction

Otherwise is possible to execute automatically the operations we write in our console:

- Write a script file *script.js*
- Execute it inside the Truffle environment (and therefore with access to Web3 etc)
  - `truffle exec script.js`
- https://www.trufflesuite.com/docs/truffle/getting-started/writing-external-scripts

Troubleshooting

Typically errors have not a not clear code or message. Here a few hints:

- Be consistent with the compiler version both in the smart contracts (pragma) and in *truffle_config.js*. Type `truffle compile --list` to see the list of available compilers. Truffle automatically fetches the version you provide if not installed
- Un-comment the Solc option “evmversion: byzantium” if you still have problems when migrating contracts also at the very beginning
    - This happens to me when I set a solidity compiler

Web3 in Python

For those who prefer Python to interact and test smart contracts web3py is easy to use

- You need to create your virtualenv and install web3
- You need to have a working network (Ganache is fine)
- You need to compile your contracts and get the ABI and Bytecode (either with Truffle or Remix)
- Write your Python code
- https://www.youtube.com/watch?v=SAi5rYFh7yw&list=PLS5SEs8ZftgVn38FOhXvLc0PoX_0hnJO9

Web3 in Python

```
import json
from web3 import Web3
# Init Web3
ganache_url = 'HTTP://127.0.0.1:8545'
web3 = Web3(Web3.HTTPProvider(ganache_url))
print("Is web3 connected: ", web3.isConnected())

# Get the data needed to create a contract
bytecode = "60806040...”
with open('Greeting.json') as json_abi:
    abi = json.load(json_abi)

# Now with the ABI and bytecode we can instantiate the Greetings contract
```

Web3 in Python

```
# Create a Greeting contract template. Greeter is “the Java class”
Greeter = web3.eth.contract(abi=abi, bytecode=bytecode)
# Call the contructor (async), you get only the transaction hash so far
      # A non-view function needs to be invoked with .transact()
tx_hash = Greeter.constructor().transact()
print(web3.toHex(tx_hash))
# Wait for the transaction to complete, get the result receipt
tx_receipt = web3.eth.waitForTransactionReceipt(tx_hash)
print(tx_receipt) # receipt

# Get the contract instance reference (i.e. the “Java object”)
contract = web3.eth.contract(abi=abi, address=tx_receipt.contractAddress)
# new_contract is the contract instance and you can finally call its functions
```

Web3 in Python

```
# Call functions
# greet() is a view function, it can be invoked with .call()
print("Contract greet: ", contract.functions.greet().call())

# setGreeting(string) is a transaction, it can be invoked with .transact() as the
contructor
tx_hash = contract.functions.setGreeting("Hola").transact()
web3.eth.waitForTransactionReceipt(tx_hash)

# calling again greet() should return a different result
print("Contract greet: ", contract.functions.greet().call())
```